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ORIGINAL ARTICLES

DETERMINATION OF THE MATURITY COEFFICIENT FOR INDIAN COTTONS

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(With four Text-figures)

THE original cell-diameter of the cotton fibre is the real measure of its fineness. In order to estimate this character various properties like the ribbon-width, swollen diameter, mercerised diameter and fibre weight per unit length are employed. Among them the fibre weight per unit length is the most easily determinable quantity. Unfortunately however, its efficiency as a criterion for fineness is vitiated by the variation of the maturity of the fibres composing the sample. For example a coarse cotton having a considerable proportion of immature fibres may give the same or sometimes smaller fibre weight per unit length than a fine cotton whose fibres are mostly mature. In order to overcome this defect in the fibre weight, Peirce and Lord [1934] conceived the idea of the 'maturity coefficient', by means of which proper weightage is given to the fibres falling within the three maturity classes. The observed fibre weight per unit length when divided by the maturity coefficient gives an expression characteristic of the strain of cotton independent of fibre-maturity. Peirce and Lord [1934] called this quantity the 'normal-hair-weight' and the square root of this quantity is proportional to the original cell-diameter of the cotton fibre. The use of the constants derived by these authors to calculate this attribute in the case of the work done in India is open to two objections, namely, (i) not many Indian Cottons were included among those studied by Peirce and Lord [1934 and 1939] and (2) the method of determining the fibre-maturity generally employed in India [Gulati and Ahmad, 1935] is somewhat different from the method employed by these authors, viz., Clegg's [1932] method. It is, therefore, necessary that for the Indian work the constants should be determined separately. This is the object of the present investigation.

MATERIAL

As already stated constants have to be obtained in order to correct the values of the fibre weight for the variation due to fibre-maturity. The material has, therefore, been chosen with a view to have the widest possible range of fibre-maturity. Among the 22 strains of cotton selected, the maturity ranged from the low value of 9.22-69 to the high value of 85.10-5. The details of the samples are recorded in Table I.

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TABLE I
Details of cottons studied

Cotton	Botanical species	Season	Place of growth	Fibre-maturity per cent			
				Mature	Half-mature	Immature	Fibre weight per cm. in — 10 gm.
1. 3915F	<i>G. Hirsutum</i>	1939-40	Indore	9.0	22.4	68.6	1.00
2. L88	<i>G. Hirsutum</i>	1940-41	Lyallpur	15.6	16.8	67.6	0.98
3. 100F	<i>G. Hirsutum</i>	1938-39	Lyallpur	17.6	14.6	67.8	0.91
4. Sind sudhar	<i>G. Hirsutum</i>	1940-41	Sakrand (Sind)	18.6	15.8	65.6	0.92
5. 4F	<i>G. Hirsutum</i>	1938-39	Lyallpur	18.8	25.8	55.4	1.29
6. Perse American	<i>G. Hirsutum</i>	1938-39	Cawnpore	22.6	23.6	53.8	1.20
7. 47F	<i>G. Hirsutum</i>	1937-38	Lyallpur	37.8	22.6	39.6	1.39
8. 3915 Q	<i>G. Hirsutum</i>	1937-38	Coimbatore	41.8	19.2	39.0	1.28
9. Kampala (commercial)	<i>G. Hirsutum</i>	1941-42	East Africa	48.4	24.6	27.0	1.62
10. Verum 262	<i>G. Arb. neg. Beng.</i>	1938-39	Nagpur	50.0	26.6	23.4	1.54
11. Koilpatti 1	<i>G. Arb. neg. Ind.</i>	1938-39	Koilpatti	50.6	20.0	29.4	1.73
12. 1027 A.L.F.	<i>G. Herbaceum</i>	1938-39	Surat	54.2	28.0	17.8	2.46
13. California (commercial)	..	..	U.S.A.	56.6	21.6	21.8	1.60
14. Jarila	<i>G. Arb. neg. Beng.</i>	1937-38	Jalgaon	56.6	22.2	21.2	1.78
15. Gadag 1	<i>G. Hirsutum</i>	1938-39	Dharwar	70.8	21.2	8.0	1.68
16. Sakels Saki (Commercial)	<i>G. Barbadensis</i>	1938-39	Egypt	72.4	19.0	8.6	1.27
17. Jayawant	<i>G. Herbaceum</i>	1938-39	Dharwar	74.8	17.4	7.8	2.80
18. Hagari 1	<i>G. Herbaceum</i>	1938-39	Hagari	74.8	16.8	8.4	2.17
19. Nandyal 14	<i>G. Arb. neg. Ind.</i>	1938-39	Nandyal	76.0	12.4	11.6	2.01
20. Gaorani 12F	<i>G. Arb. neg. Ind.</i>	1940-41	Hyderabad	77.4	12.0	10.6	2.25
21. Verum 434	<i>G. Arb. neg. Beng.</i>	1938-39	Akola	79.0	12.8	8.2	2.17
22. Mollisoni	<i>G. Arb. neg. Beng.</i>	1938-39	Lyallpur	85.0	10.0	5.0	2.93

It will be noticed that the cottons have been arranged in the ascending order of fibre-maturity and are divided into three groups. The first group contains cottons of low fibre-maturity, the second those of medium maturity while the third group contains cottons of high maturity. This division should not be taken to mean that any standards of fibre-maturity have been prescribed for purposes of classification. A glance at the maturity figures reveals that the cottons automatically divide themselves into the three groups, the limits being quite arbitrary. It will also be noticed that the samples chosen, besides having the wide range of fibre-maturity possible, also represent the range of cottons cultivated in India, from the

point of view of the botanical species and of the place of growth. Three foreign cottons A. R. Kampala, California and Sakels Saki are included in the study in order to see how the results obtained for these cottons compared with those for the Indian cottons.

It should not be misunderstood that some of the low values of fibre-maturity recorded in Table I for some of the cottons is a general feature for these cottons. In fact, they are some abnormal values and as we required cotton samples having low fibre-maturity, these samples were chosen.

EXPERIMENTAL PROCEDURE

A representative sliver was prepared out of the sample of lint and a tuft of about 500 fibres was pulled out from it and kept on a piece of plush. Fibres from this tuft were taken out and mounted on a slide parallel to one another and perpendicular to the length of the slide using seccotine. Twenty fibre were mounted on each slide and a wide gap was left after each group of five fibres so that the rank of the fibre under examination could be easily known at any stage. The fibres were fairly stretched while mounting and a thin layer of Dunlop rubber solution was smeared over the ends of the fibres, as otherwise the binding action of the seccotine would be weakened by contact with the caustic soda solution. A long cover-slip five millimeters wide was used to cover the fibres.

The fibres were first viewed in the raw state under polarised light by the method developed by Schwarz and others [1935 and 1938] and the maturity class of each fibre was recorded. They were then irrigated with eighteen per cent caustic soda solution and the maturity class of each fibre according to Gulati and Ahmad's [1935] method was also noted. In the beginning the allocation of the maturity class according to the polarised light method and the swelling method showed some divergence for some of the fibres lying on the borderland. But after some experience this number was reduced to about ten out of the 500 fibres examined for each cotton. Next the diameter of the fibre and the diameter of the lumen at the same place were recorded at five random places nearly equally apart along the five mm. length of the fibre under the coverslip.

As the fibres were originally fairly stretched, the contraction caused by the swelling in the alkali solution stretched them still further so that the fibres appeared like straight cylinders or tubes of different wall-thickness depending upon the degree of maturity of the fibre, the lumen also being clearly visible. The diaphragm of the microscope was made as small as possible and the condenser lens was lowered to the required extent to make the definition of the image of the fibre and the lumen very clear so that the measurements could be made quite accurately.

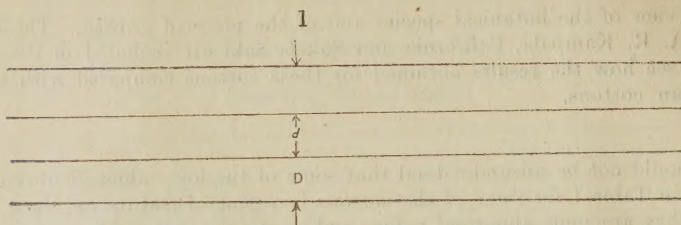


FIG. 1. Longitudinal section of a swollen cotton fibre which is partially thickened

THEORETICAL BASIS

If D is the diameter of a fibre and d the diameter of its lumen as shown in Fig. 1 volume of the cellulose inside unit length of the fibre is given by $\frac{\pi}{4} (D^2 - d^2)$. If no lumen were present, as in the case of a fully mature fibre, the volume of the cellulose would have been $\frac{\pi}{4} D^2$. The ratio of the two is $\frac{D^2 - d^2}{D^2}$ or $1 - \frac{d^2}{D^2}$.

This expression is the maturity coefficient of the fibre under consideration expressed in terms of the volume of cellulose. The same expression would stand in terms of the weight of cellulose also, if the weight of cellulose in unit volume of the swollen cellulose were constant in all the different types of fibres. *A priori* reasoning, however, indicates that this cannot be the case, for while inside the immature and half-mature and some of the mature fibres the lumen space provides room for the expansion of the swollen cellulose, inside mature fibres having no lumen, there is no such space for expansion. In the latter case, therefore, the cellulose should be under greater pressure and consequently having a greater 'density'* than in the case of the other fibres. It is, however, not possible to determine the 'density' in each individual fibre but the average value for each maturity class may be estimated, the method of doing which will be described later.

It was stated earlier that the maturity class of each fibre was recorded. For the fibres falling within the mature class the individual values of $1 - \frac{d^2}{D^2}$ could be

grouped together and their mean value, α , calculated. After similar grouping the mean values of the ratio for the half-mature class, β , and for the immature class, γ , could be obtained. These values, as already stated before, require correction for the change in the 'density' of cellulose and after applying the necessary corrections the respective values α , β and γ could be determined. If M , H and I are the percentages of the mature, half-mature and immature fibres respectively in the sample, the maturity coefficient is given by

$$M_c = \frac{\alpha M + \beta H + \gamma I}{100} \quad (1)$$

*The expression 'density' of cellulose used in this paper means the weight of cellulose only per unit volume of the swollen cellulose.

By dividing the fibre weight by this coefficient we get the weight of a mature fibre in which the lumen is completely absent. If, on the other hand, our basis is what we normally call a mature fibre, then α may be taken as the unit, when the maturity coefficient would be changed to

$$M_c = \frac{M + \beta/\alpha H + \gamma/\alpha I}{100} \quad (2)$$

The method of calculating the 'density' of cellulose inside the swollen mature, half-mature and immature fibres may now be considered. As already stated before

$\frac{\Pi}{4} (D^2 - d^2)$ gives the volume of cellulose inside a unit length of the fibre.* If ρ

is the 'density' of cellulose, then the weight of the cellulose is $\frac{\Pi}{4} (D^2 - d^2)$.

The mean value of this expression for all the 500 fibres examined should give the mean weight of cellulose per unit length for the sample of cotton under study. This quantity could be obtained in another way from the fibre weight which, for this purpose, was determined by weighing 2,000 fibres for each sample. As in the present study the central region of the fibre was used for diameter measurements, centimeter lengths cut from the middle of the fibres were used for weighing also: It is well known that the weight of the fibre is made up of cellulose, moisture, mineral matter, wax, etc. According to Marsh and Wood [1942] 'some typical data on the constituents of raw cotton are 90 per cent of cellulose, eight per cent of moisture, one per cent of mineral matter, 0.5 per cent of wax, etc., and 0.5 per cent of pectic matter' and these values can be taken as approximately true for Indian cottons also. In the present work as the fibre weight has been corrected to 70 per cent R.H. the moisture content practically corresponds to eight per cent stated above and therefore, 90 per cent of the fibre weight may be taken as equivalent to the weight of the cellulose. Of course this percentage may vary a little from cotton to cotton but on the average the variations may balance one another so that they do not influence the final conclusions. If the value of the cellulose weight per cm. is taken as 0.9F, where F is the fibre-weight per cm., then

$$\frac{\Pi}{4} (D^2 - d^2) \rho = 0.9F \quad (3)$$

Or

$$\rho = \frac{3.6F}{\Pi (D^2 - d^2)} \quad (4)$$

From equation (4) the value of ρ could be calculated. If ρ_m , ρ_H and ρ_I are the mean values of ρ for the mature, half-mature and immature fibres respectively

* As the fibre is held stretched there is no contraction in length due to the action of caustic soda.

and since M, H and I are the percentages of the respective class of fibres, it may be stated that

$$\rho = \frac{M \rho_M + H \rho_H + I \rho_I}{100} \quad (5)$$

Such equations are obtained for each of the 22 cottons examined and from the 22 equations, employing the usual partial regression method, Fisher [1936], taking ρ as Y and M, H and I as X_1 , X_2 and X_3 respectively, the values of ρ_M , ρ_H and ρ_I could be calculated. These values were found to be 0.52 gm. per c.c. for the mature fibres, 0.36 for the half-mature fibres and 0.38 for the immature fibres. It will be noticed that the value for the mature fibres is considerably higher than that for the other two, the difference between which is almost negligible. This finding, it will be remembered, is the same as what was anticipated previously from a *priori* considerations. As the value of ρ for both the latter classes of fibres is found to be nearly the same, it would be more appropriate to take the mean value for both the classes which we may call ρ_{HI} . A more correct estimate of this quantity could, however, be obtained by dividing the fibres into two classes only, namely, the mature and non-mature, when equation (5) would be modified into

$$\rho = \frac{M \rho_M + (100-M) \rho_{HI}}{100} \quad (5a)$$

The values of ρ_M and ρ_{HI} obtained from the 22 such equations were found to be 0.52 and 0.38 respectively. It will be observed that the former value is the same as that got before while the latter differs from the previous value by 0.01 only. The present value, being the more correct one, has been used in all the calculations.

RESULTS

(a) *Ratio $1-d^2/D^2$: Distribution in each maturity class.*—It was stated above that the ratio $1-d^2/D^2$ represents the maturity coefficient of the fibre in terms of the volume of the swollen cellulose. It is first necessary to determine the values of this ratio that correspond to the border lines between the mature and half-mature fibres and between half-mature and immature fibres. This is done as follows. It was already mentioned that the maturity class of each fibre was recorded following the method of Gulati and Ahmad [1935]. The values of the ratio $1-\frac{d^2}{D^2}$ for all the fibres falling within the mature class are grouped together; similarly those for the fibres within the half-mature and immature classes respectively are also grouped. The data obtained in the case of medium mature cotton, Verum 262, are shown in Fig. 2. It will be seen that for the immature fibres the values range from 0.34 to 0.73, for the half-mature fibres from 0.64 to 0.94 and for the mature fibres from 0.85 to 1.0. The border lines are not clearly defined as there is some overlapping in these regions. This is bound to be the case as the estimation of

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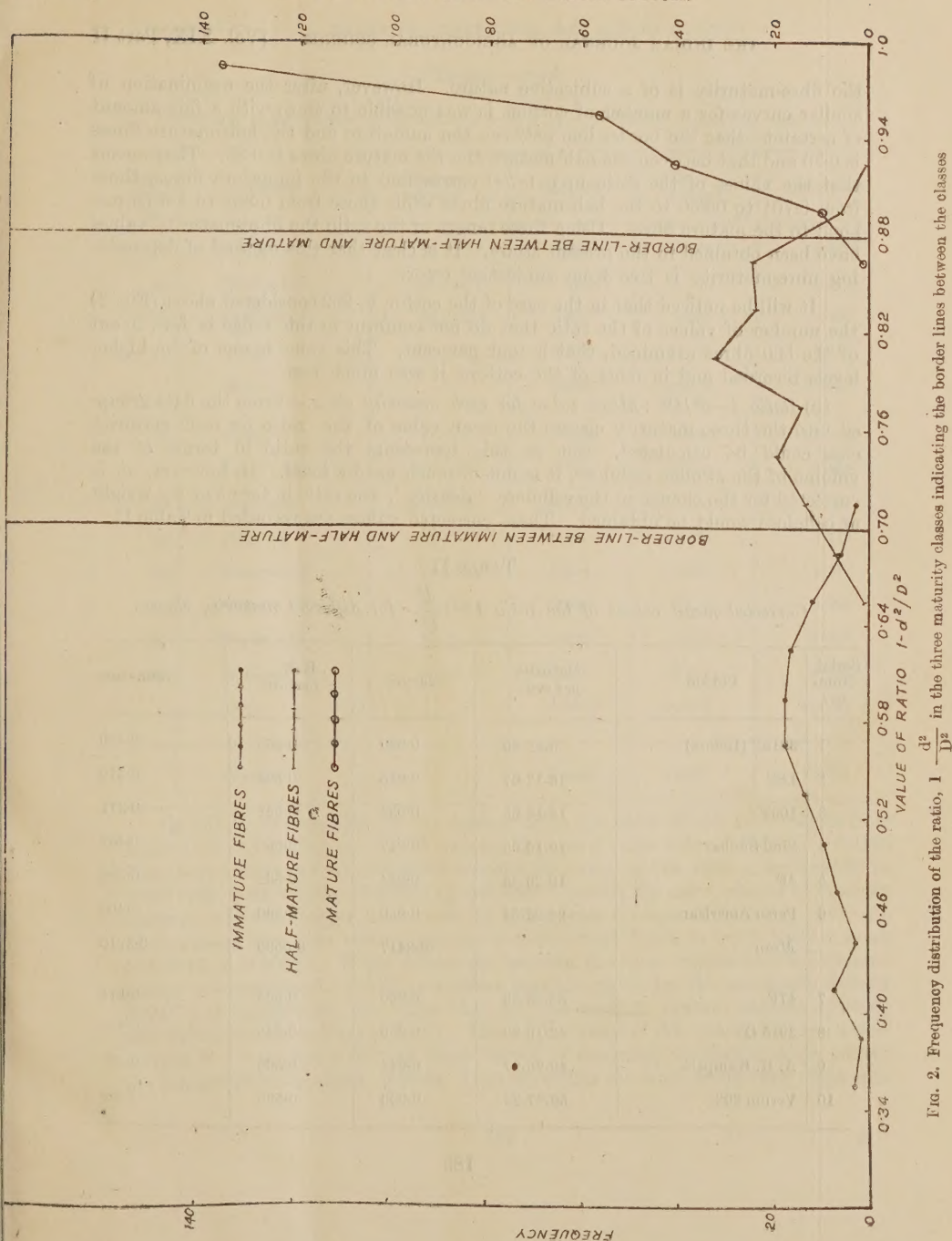


FIG. 2. Frequency distribution of the ratio, $1 - \frac{d^2}{D^2}$ in the three maturity classes indicating the border lines between the classes

the fibre-maturity is of a subjective nature. However, after the examination of similar curves for a number of cottons it was possible to state with a fair amount of certainty that the border line between the immature and the half-mature fibres is 0.70 and that between the half-mature and the mature fibres is 0.88. That means that the values of the ratio up to 0.700 correspond to the immature fibres, those from 0.701 to 0.880 to the half-mature fibres while those from 0.881 to 1.0 correspond to the mature fibres. Using these ranges of the ratio the fibre-maturity values have been obtained in the present study. It is clear that this method of determining fibre-maturity is free from subjective error.

It will be noticed that in the case of the cotton V. 262 considered above (Fig. 2) the number of values of the ratio that do not conform to this range is few, 20 out of the 500 fibres examined, that is four per cent. This value is one of the higher levels recorded and in most of the cottons it was much less.

(b) *Ratio $1-d^2/D^2$: Mean value for each maturity class.*—From the data grouped into the three maturity classes the mean value of the ratio for each maturity class could be calculated. But as this represents the ratio in terms of the volume of the swollen cellulose, it is not of much use by itself. If, however, it is corrected for the change in the cellulose 'density', the ratio in terms of the weight of cellulose would be obtained. These corrected values are recorded in Table II.

TABLE II

Corrected mean values of the ratio $1 - \frac{d^2}{D^2}$ for different maturity classes

Serial Number	Cotton	Maturity per cent	Mature	Half mature	Immature
1	3915F (Indore)	9.22-69	0.930	0.550	0.400
2	LSS	16.17-67	0.945	0.562	0.379
3	100F	18.14-68	0.934	0.558	0.371
4	Sind Sudhar	19.16-65	0.947	0.562	0.402
5	4F	19.26-55	0.944	0.562	0.388
6	Perso American	23.23-54	0.950	0.560	0.406
	<i>Mean</i>	..	0.9417	0.5590	0.3910
7	47F	38.23-39	0.960	0.565	0.374
8	3915 Q	42.19-39	0.966	0.548	0.395
9	A. R. Kampala	48.25-27	0.944	0.566	0.429
10	Verum 262	50.27-23	0.966	0.565	0.403

TABLE—*contd.*Corrected mean values of the ratio $1 - \frac{d^2}{D^2}$ for different maturity classes

Serial Number	Cotton	Maturity per cent	Mature	Half mature	Immature
11	Koilpatti 1	51-20-29	0.973	0.577	0.375
12	1027 A.L.F.	55-28-17	0.962	0.578	0.399
13	California	57-21-22	0.950	0.565	0.427
14	Jarila	57-22-21	0.961	0.575	0.395
	<i>Mean</i>	..	0.9602	0.5669	0.3999
15	Gadag 1	71-21- 8	0.954	0.582	0.448
16	Sakel's Saki	72-19- 9	0.955	0.585	0.443
17	Jayawant	75-17- 8	0.953	0.585	0.408
18	Hagari 1	75-17- 8	0.960	0.578	0.422
19	Nandyal 14	76-12-12	0.964	0.580	0.416
20	Gaorani 12F	77-12-11	0.968	0.573	0.429
21	Verum 434	79-13- 8	0.975	0.585	0.445
22	Mollisoni	85-10- 5	0.966	0.576	0.422
	<i>Mean</i>	..	0.9619	0.5805	0.4291
	<i>Mean</i>	..	0.9558	0.5697	0.4081

It will be noticed that for the mature fibres the value of this ratio ranges from 0.930 to 0.975 among all the 22 cottons, the mean value being 0.9558 ± 0.00258 . However, among the six immature cottons the range of the ratio is from 0.930 to 0.950 only, with a mean of 0.9417 ± 0.00350 . Among the eight cottons of medium maturity the ratio ranges from 0.944 to 0.973 with a mean of 0.9602 ± 0.00459 , while among the eight mature cottons it varies from 0.953 to 0.975 with a mean of 0.9619 ± 0.00383 . If the differences between the mean values for the different groups are considered, it will be noticed that the value for the immature cottons (0.9417) is significantly less than that for the medium mature cottons (0.9602) and for the mature cottons (0.9619). The smaller value of the ratio for the immature cottons is due to the relatively lesser degree of secondary thickening even among the mature fibres in these cottons. That is, within the wide group that represents

the mature fibres relatively more of them lie nearer the lower border line of the ratio. Or in other words there is a shift in the maturity towards the lower limit of the maturity class. The possibility of such occurrence has been dealt with from *a priori* considerations by Peirce and Lord [1934,] also.

Coming to the half-mature fibres, the value of the ratio is found to range from 0.548 to 0.585 among all the 22 cottons the mean value being 0.5697 ± 0.00256 . For the six immature cottons it varies from 0.550 to 0.562 with a mean of 0.5590 ± 0.00183 , for the medium mature cottons from 0.548 to 0.578 with a mean of 0.5669 ± 0.00348 , while for the mature cottons it ranges from 0.573 to 0.585 with a mean of 0.5805 ± 0.00208 . The value for the mature cottons (0.5805) is significantly greater than that for the medium mature cottons (0.5669), and for immature cottons (0.5590).

Coming next to the immature fibres, the mean values of the ratio is found to range from 0.371 to 0.448, having a mean value of 0.408 ± 0.00509 . For the immature cottons it varies from 0.371 to 0.406, with a mean of 0.3910 ± 0.00432 , for the medium mature cottons from 0.374 to 0.427 with a mean of 0.3999 ± 0.00748 while for the mature cottons it ranges from 0.408 to 0.448 with a mean of 0.4291 ± 0.00591 . The significances of the differences between the mean values for the different groups are the same as observed in the case of the half-mature fibres. The cause for the differences observed in the case of both half-mature fibres and immature fibres is the same as was stated in the case of the mature fibres, namely, the shift of the degree of maturity within a maturity class itself towards the lower limits of maturity in the less mature cottons.

The behaviour of the three foreign grown cottons may now be considered. It will be noticed that the values of the ratio for Sakels 'Saki' are nearly the same as for the other Indian cottons of similar fibre maturity, though the standard error (0.00297) of the mean value of the ratio for the immature fibres (0.443) is very much smaller than the values normally observed. In the other two cottons, A.R. Kampala and California, the value of the ratio for the half-mature fibres is nearly the same as for the other Indian cottons of similar fibre maturity but on the other hand the value for the mature fibres appears to be smaller and for the immature fibres greater than the corresponding values for similar Indian cottons. The consequences of this variation will be examined later.

(c) *Maturity coefficient*.—Using the mean values of the ratios obtained above the maturity coefficient could be calculated according to (1) which comes to

$$M_c = \frac{0.9558M + 0.5697H + 0.4081 I}{100} \quad (6)$$

But if, as already stated before, we have as our basis what we normally call a mature fibre then the coefficient could be calculated according to (2) which comes to

$$M_c = \frac{M + 0.596H + 0.427 I}{100} \quad (7)$$

Before deciding on this equation as the final form we have to bear in mind the fact that the values of α , β and γ for the different groups of cottons are significantly different from one another in some cases. This gives the impression that the maturity coefficient calculated by using the individual mean values of the ratio obtained for each group of cotton would be a more accurate estimate. The three separate equations are as follows. For immature cottons

$$M_c = \frac{M + 0.594H + 0.415 I}{100} \quad (8)$$

for medium mature cottons

$$M_c = \frac{M + 0.590H + 0.416 I}{100} \quad (9)$$

and for mature cottons

$$M_c = \frac{M + 0.604H + 0.446 I}{100} \quad (10)$$

The values of the maturity coefficient calculated by using the separate equations for the different groups and also the single equation for all the groups along with the differences between the respective values are recorded in Table III.

It will be noticed that for immature and medium mature cottons the single equation gives a higher value than the separate equations for each of these groups, though, however, the differences are very small, the average value being 0.0078 for the former and 0.0048 for the latter cottons. On the other hand in the case of the mature cottons the single equation gives a lower value than the separate equations and the differences are even smaller in magnitude in this case, the mean value being only 0.0030. From the foregoing it is clear that the replacement of several equations by a single equation has produced negligible variation in the value of the maturity coefficient.

One other point requires to be considered. The constants for the single equation, 0.596 and 0.427, were obtained from the arithmetic means of the 22 values. But from what has already been stated the value of the constant is to some extent influenced by the fibre maturity of the sample. Therefore, it would be more appropriate to take the weighed mean values. The weighing was done by using the values of the percentage of mature fibres for α , those of halfmature fibres for β and those of immature fibres for γ . Consequent on this the values of the constants were modified to 0.592 for half-mature fibres and 0.414 for immature fibres. It will be noticed from Table III that these values are subject to errors which make the third place not quite reliable. If, therefore, they are rounded up correct to the second place of decimals they become 0.59 and 0.41 respectively. As these

Table III

Values of the maturity coefficient obtained from different formulae

Serial number	Cotton	Separate equations (8), (9) and (10)	Single equation (7)	Difference A-B	Single equation (11) present formula C	Difference A-C	Equation (12) P and L's old formula D	Difference C-D	Equation (13) P and L's new formula E	Difference C-E	Derived from Equation (20) F	Difference C-F	Fibre weight per cm 10-6 gm.
1	3915 F (Indore)	0.508	0.516	-0.008	0.499	+0.009	0.567	-0.068	-0.335	+0.164	0.486	+0.013	1.00
2	1856 F	0.536	0.537	-0.001	0.527	+0.009	0.586	-0.059	0.367	+0.160	0.516	+0.011	0.98
3	3915 F	0.534	0.535	-0.001	0.535	+0.000	0.591	-0.056	0.374	+0.159	0.524	+0.011	0.91
4	Shri Sudhar	0.552	0.560	-0.008	0.543	+0.009	0.600	-0.057	0.387	+0.166	0.533	+0.010	0.92
5	4F	0.571	0.578	-0.007	0.561	+0.007	0.631	-0.067	0.411	+0.133	0.556	+0.008	1.20
6	Perso American	0.589	0.596	-0.007	0.583	+0.006	0.645	-0.062	0.453	+0.130	0.575	+0.008	1.20
<i>Mean</i>													
7	47F	..	..	-0.0078	..	+0.0632	..	-0.0615	..	+0.1507	..	+0.0101	..
8	3915 Q	0.676	0.682	-0.006	0.672	+0.004	0.726	-0.054	0.576	+0.096	0.670	+0.002	1.39
9	A.R. Kapurda	0.706	0.706	-0.000	0.689	+0.005	0.738	-0.049	0.595	+0.084	0.688	+0.001	1.38
10	Verum 292	0.741	0.746	-0.005	0.710	+0.001	0.700	-0.050	0.672	+0.068	0.742	-0.002	1.52
11	Kodipadi I	0.746	0.751	-0.004	0.753	+0.001	0.805	-0.052	0.694	+0.059	0.756	-0.003	1.54
12	1027 A.L.F.	0.781	0.785	-0.004	0.781	+0.000	0.832	-0.051	0.735	+0.072	0.746	-0.002	1.73
13	California	0.784	0.789	-0.005	0.783	+0.001	0.826	-0.043	0.728	+0.046	0.780	-0.003	2.46
14	Jarila	0.785	0.789	-0.004	0.784	+0.001	0.828	-0.044	0.731	+0.055	0.787	-0.003	1.60
<i>Mean</i>													
15	Gadar I	..	..	-0.0043	..	+0.0019	..	-0.0484	..	+0.0679	..	-0.0022	..
16	Sake's Sakl'	0.872	0.869	+0.003	0.867	+0.005	0.905	-0.036	0.845	+0.022	0.877	-0.010	1.68
17	Jayavanti	0.877	0.874	+0.003	0.872	+0.005	0.905	-0.033	0.849	+0.023	0.882	-0.010	1.27
18	Hazari I	0.885	0.885	+0.003	0.884	+0.004	0.914	-0.030	0.862	+0.022	0.894	-0.010	2.30
19	Nandyal 14	0.887	0.883	+0.003	0.882	+0.005	0.912	-0.030	0.860	+0.022	0.893	-0.010	2.17
20	Gaonani 12F	0.894	0.891	+0.003	0.888	+0.006	0.912	-0.024	0.862	+0.023	0.891	-0.010	2.34
21	Verum 434	0.901	0.904	+0.003	0.900	+0.004	0.923	-0.023	0.877	+0.022	0.899	-0.011	2.17
22	Mollisoni	0.933	0.931	+0.002	0.930	+0.003	0.948	-0.018	0.917	+0.013	0.943	-0.013	2.63
<i>Mean</i>													
23	..	..	..	+0.0030	..	+0.0048	..	-0.0272	..	+0.0224	..	-0.0108	..
<i>Mean</i>													
24	..	..	..	-0.0028	..	+0.0046	..	-0.0443	..	+0.0739	..	-0.0020	..

values do not differ much from 0.6 and 0.4 respectively and as the latter are more easy to remember they may be used instead, when equation (7) gets simplified to

$$M_c = \frac{M + 0.6 H + 0.4 I}{100} \quad (11)$$

It is now necessary to find out the error that is introduced by the simplification. This can be done by comparing the value of M_c obtained from (11) with those obtained from (8) (9) and (10)*. It will be noticed (Table III) that in all the 22 cottons except one, equation (11) gives a smaller value. The difference, however, is very small in magnitude ranging from 0.000 to 0.009 with a mean value of 0.0046, which means that the accuracy of the formula has not suffered by the simplification.

Yet another point requires consideration and that is regarding the inclusion of the three foreign cottons. This is specially necessary in view of the fact already mentioned, that two of these three cottons indicated somewhat different values of the ratios for the mature and immature fibres. Therefore, the constants were recalculated omitting these three cottons but the values obtained were found to be practically the same as those got previously, the differences produced being negligible. Hence it is not necessary to exclude the three foreign cottons from our analysis.

It should be remembered, however, that the constants derived above have been obtained indirectly from the volume and other dimensions of the fibre. A direct verification by actual weighing should be of considerable value. Such weighing was done by Peirce and Lord [1939, T. 186] and they used fibres swollen in caustic soda solution and separated into the three maturity classes. The difficulties involved in handling the very tiny bundles of slippery cm. long fibres swollen in the alkali, the removal of the alkali from them by washing are indeed great. Besides during these processes it is quite likely that some of the fibres may slip out and thus create errors. Therefore in the present work the fibres were weighed in the raw state after being separated into the mature, half-mature and immature classes by using the polarised light technique of Schwarz and others [1935 and 1938] already mentioned. After the examination of 22 cottons good experience had been gained for the proper allocation of the maturity class by that method. Fibres cut to cm. lengths were viewed individually under polarised light, the maturity class of each fibre was ascertained and the fibres falling within the mature, half-mature and immature classes were collected each in a separate pouch suitably designated. Two lots of 800 to 900 fibres each were examined for each sample and in that way four samples of cotton were tested, the testing of more samples being precluded by the strenuous nature of the work. The results obtained are given in Table IV.

*Equations (8), (9) and (10) have been derived from the arithmetic mean values of α , β and γ for each group of cottons and from the previous reasoning it would be more appropriate to use the weighed mean values in these cases also. When this modification was made it was found that no difference was observed in the value of M_c , upto the third place of decimals which is the last place taken in the present study, so far as equations (8) and (10) are concerned. However, in the case of equation (9) there was a difference of one unit in the third place in a few cottons only. Hence there would be little objection in using equations (8), (9) and (10) without modification for purposes of comparison.

TABLE IV

Ratio of the weight of a mature, half-mature and immature fibre to the weight of a mature fibre

Cotton	Mature	Half-mature	Immature
Perso American	1	0.65	0.41
47F	1	0.66	0.39
Verum 262 (1)	1	0.63	0.40
Verum 262 (2)	1	0.66	0.39
<i>Mean</i>	1	0.65	0.40

It will be noticed that in all the four samples of cotton the values of each ratio lie close to one another. The mean value* for the immature fibres, 0.40, coincides with that used in equation (11). However, the value for the half-mature fibres, 0.65, appears to be rather higher than the previous value 0.6. It should be noted that the former figure is derived from four samples of cotton only, while the latter one is derived from 22 samples of cotton. Furthermore by using 0.65 in place of 0.6 in equation (11) the value of the maturity coefficient is altered by a very small amount only. For these reasons equation (11) may be allowed to stand without any modification.

(d) *Comparison of the formulae.* The formula for the calculation of M_c obtained in the present work is

$$M_c = \frac{M + 0.6H + 0.4 I}{100} \quad (11)$$

The old formula of Peirce and Lord [1934] is

$$M_c = \frac{M + 0.75H + 0.45 I}{100} \quad (12)$$

†The new formula of Peirce and Lord (1939) is

$$M_c = \frac{1}{1.2} \left\{ \frac{1}{2}(M-I)/100 + 0.7 \right\} \quad (13)$$

*The values recorded here have been obtained by correcting the weights of the mature, half-mature and immature fibres to those at 70 per cent R.H., pre-supposing that the moisture absorption capacity of each of the three types of fibres is the same. Whether it is so or if different whether it affects the values got here is dealt with in the appendix.

†In the paper by Peirce and Lord [1939] the quantity, maturity ratio (M_c) alone, has been considered. The maturity coefficient (M_c) can be derived from it in the following manner. If F is the fibre weight of a sample of cotton and if F_s and F_m are the values of F for standard (67-26.7) and complete (100-0.0) maturity respectively, then (continued on page 195. Footnote).

Therefore we can write

$$\text{II} \quad \frac{D^2 \rho M}{4} = \frac{0.9F}{M_c \times 0.9558}$$

$$\text{Or } D = \sqrt{\left\{ \frac{3.6F}{0.9558 \text{ II. } \rho M M_c} \right\}} \quad (18)$$

With the help of this equation the diameter could be predicted using the value of M_c got from (11), (12) and (13), and the predicted value in each case could be compared with the actual mean value of the diameter obtained microscopically. The closeness of the agreement is an indication of the efficiency of the particular formula. The results obtained are recorded in Table V.

It will be noticed that the difference (col. 6) between the actual value of the diameter and the value predicted by using the formula derived in the present investigation expressed as a percentage of the former, ranges from -3.3 to $+6.3$ per cent, the mean difference for all the cottons taken together being $+0.66 \pm 0.534$, which is not significant. If the three groups are considered separately, it will be seen that the mean value for the mature cottons is $+1.46 \pm 0.895$ and for the medium mature cottons -0.30 ± 0.859 , while for the immature cottons it is $\pm 0.87 \pm 1.046$, all the differences being non-significant. It follows, therefore, that the diameter predicted by using the present formula agrees closely with that obtained microscopically for all types of cottons. It will also be noted in Fig. 3 that the differences observed in this case lie on either side of zero and are independent of the immaturity of the sample.

Coming next to the difference (col. 8) between the value of the diameter predicted using the old formula of Peirce and Lord and the actual value, it is found to vary from -7.8 to $+5.0$ per cent, the mean difference for all cottons being $-2.47^{**} \pm 0.629$, which is significant. For the mature group of cottons, however, the mean difference is $+0.05 \pm 0.900$ which is not significant. On the other hand for the medium mature group it is $-3.42^{**} \pm 0.743$ significant and for the immature group it is $-4.7^{**} \pm 0.864$ also significant. Which means that except for the mature cottons, for which there is agreement in the other two groups of less mature cottons the diameter predicted by using the old formula of Peirce and Lord [1934] is significantly smaller though, however, the deficit is small and cannot be considered to be of much consequence if some error is tolerated, as can also be seen in Fig. 3.

Next if we consider the values predicted from the new formula of Peirce and Lord it will be noted that the difference (col. 10) is generally much larger, ranging from 0.0 to $+27.8$ per cent. All the differences excepting the one which is zero are positive indicating that the predicted value in this case is generally higher. The mean difference for all the 22 cottons is $+7.92^{**} \pm 1.645$, which is significant. That for the mature group of cottons, $+2.81^* \pm 0.928$, though small is significant, while for the medium mature group it is $+4.80^{**} \pm 1.194$ also significant and for the immature group it is as large as $+3.90^{**} \pm 1.931$ per cent, of course significant.

TABLE V
Values of fibre diameter (in μ) obtained microscopically and predicted by using M_c calculated by different formulae

Serial number	Cotton	Maturity per cent	Microscopical value	From fibre weight maturity coefficient						Modified P and L (New)	
				Equation (11) Present		Equation (12) P and L (Old)		Equation (13) P and L (New)			
				Value	Difference per cent	Value	Difference per cent	Value	Difference per cent	Value	Difference per cent
1	3915F (Indore)	9-25-69	20.5	21.5	+4.9	20.2	-1.5	26.2	+27.8	21.8	+6.3
2	LSS	16-17-67	20.8	20.7	-0.5	19.6	-5.8	24.8	+19.2	20.9	+0.5
3	100F	18-14-68	20.4	19.8	-2.9	18.8	-7.8	23.7	+16.2	20.0	-2.0
4	Sind Sudhar	19-16-65	19.6	19.8	+1.0	18.8	-4.1	23.4	+19.4	19.9	+1.5
5	4F	19-26-55	22.7	23.0	+1.3	21.7	-4.4	26.3	+15.9	23.1	+1.8
6	Perso American	23-23-54	21.5	21.8	+1.4	20.7	-3.7	24.7	+14.9	21.9	+1.9
	Mean	..	...	..	+0.87	..	-4.55**	..	+18.90**	..	+1.0
	S.E.	± 1.046	..	± 0.864	..	± 1.931	..	± 1.101
7	47F	38-23-39	21.6	21.8	+0.9	21.0	-2.8	23.6	+9.3	21.9	+1.4
8	3915Q	42-19-39	20.9	20.7	-1.0	20.0	-4.3	22.3	+6.7	20.7	-1.0
9	A. R. Kampala	48-25-27	21.6	22.5	+4.2	21.7	+0.5	23.6	+9.3	22.4	+3.7
10	Verum 262	50-27-23	21.6	21.7	+0.5	21.0	-2.8	22.6	+4.6	21.7	+0.5
11	Kollpratti 1	51-20-29	24.0	23.2	-3.3	22.5	-6.2	24.4	+1.7	23.1	-3.8
12	1027 A.L.F.	55-28-17	26.7	26.9	+0.7	26.1	-2.2	27.8	+4.1	26.9	+0.7
13	California	57-21-22	22.0	21.7	-1.4	21.1	-4.1	22.5	+2.3	21.6	-1.8
14	Jarlia	57-22-21	23.6	22.9	-3.0	22.3	-5.5	23.7	+0.4	22.8	-3.4
	Mean	..	..	..	-0.30	..	-8.42**	..	+4.80**	..	-0.46
	S.E.	± 0.859	..	± 0.743	..	± 1.194	..	± 0.896

TABLE V—*contd.*
Values of fibre transfer (in u) obtained microscopically and predicted by using M_c calculated by different formulae

Serial number	Cotton	Maturity per cent	Microscopical value	From fibre weight maturity coefficient							
				Equation (11) Present		Equation (12) and L (Old)		Equation (13) P and L (New)		Modified P and L (New)	
				value	Difference per cent	value	Difference per cent	value	Difference per cent	value	Difference per cent
15	Gadag 1	71-21-8	21-0	21-1	+0-5	20-7	-1-4	21-4	+1-9	21-0	0-0
16	Sakels 'Saki'	72-19-9	18-0	18-3	-1-3	18-0	-2-3	18-6	0-0	18-2	-2-2
17	Jayawant	75-17-8	23-8	24-5	+2-9	24-1	+1-3	24-9	+4-2	24-4	+2-5
18	Hagari 1	75-17-8	23-6	23-8	+0-8	23-4	-0-8	24-1	+2-1	23-7	+0-4
19	Nandyal 14	76-12-12	22-2	22-9	+3-2	22-6	+1-8	23-3	+5-0	22-8	+2-7
20	Goarai 12'	77-12-11	24-2	24-2	0-0	23-9	-1-2	24-5	+1-2	24-0	-0-8
21	Verum 434	79-13-8	22-2	23-6	+6-3	23-3	+5-0	23-9	+7-7	23-4	+5-4
22	Mollisoni	85-10-5	27-0	26-9	-0-4	26-7	-1-1	27-1	+0-4	26-8	-0-7
	Mean	..	..	..	+1-40	..	+0-05	..	+2-81*	..	+0-91
	S.E.	..	..	..	± 0-895	..	± 0-900	..	± 0-928	..	± 0-868
	Mean	..	..	..	+0-66	..	-2-17*	..	-7-92*	..	+0-62
	S.E.	..	..	..	± 0-534	..	± 0-629	..	± 1-645	..	± 0-551

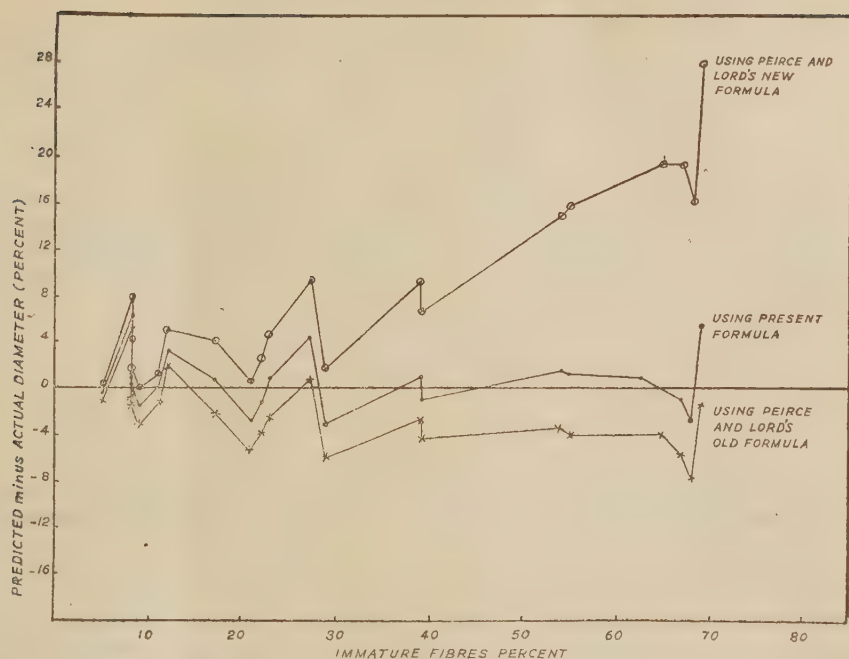


FIG. 3. Departure of the predicted value of the diameter, using the present formula the old and new formulas of Peirce and Lord, from its true value in relation to the fibre immaturity of the sample of cotton

It follows, therefore, that for the mature group of cottons the difference is small, for the medium mature group it is somewhat larger while for the immature group it is much larger indeed. There is a clear tendency for the difference to increase with the increase of immaturity of the sample, as can be seen in Fig. 3, unlike what was observed in the two previous cases.

From the foregoing it is clear that the present formula is quite satisfactory. The old formula of Peirce and Lord, though satisfactory for mature cottons appears to be somewhat defective for immature (Indian) cottons. Their new formula may be taken as valid for (Indian) cottons of good maturity but should be considered definitely erroneous for immature (Indian) cottons. It follows that while for the mature cottons all the three formulae appear to be satisfactory, for the immature cottons the new formula of Peirce and Lord should be considered definitely defective.

The cause of this defect may now be enquired into. Rewriting (11) we have

$$100M_c = M + 0.6H + 0.4I \quad (11a)$$

$$\text{Since } H = 100 - M - I$$

$$\begin{aligned} 100M_c &= M + 60 - 0.6M - 0.6I + 0.4I \\ &= 0.4M - 0.2I + 60 \\ &= 0.4(M - \frac{1}{2}I) + 60 \end{aligned} \quad (19)$$

To get M_r we have to multiply M_c by F_m/F_r as already shown in the footnote of p. 198. Using (11) and following the same procedure as done in the footnote and assuming with Peirce and Lord [1939] the standard maturity to be 67.26-7, it can be easily shown that $F_m/F_r = 1.171$. Therefore, multiplying both sides of (19) by 1.171 we have,

$$117.1 M_c = 100 M_r = 0.468 (M - \frac{1}{2} I) + 70.3$$

$$\text{On approximately } 100 M_r = \frac{1}{2}(M - \frac{1}{2} I) + 70$$

$$\text{Or } M_r = \frac{\frac{1}{2}(M - \frac{1}{2} I) + 70}{100} \quad (20)$$

which, surprisingly enough, is the same as the new formula of Peirce and Lord, except that I is replaced by $\frac{1}{2}I$, that is, a lower weighing is given for the immature fibres.

The validity of this formula could be verified, as was done before, by comparing the diameter predicted by using this formula with the actual value. This comparison is shown in the last two columns of Table V. It will be noticed that the mean difference for all the cottons taken together is $+0.62 \pm 0.551$, for the mature group of cottons $+0.91 \pm 0.868$, for the medium mature group -0.46 ± 0.896 and for the immature group it is 1.67 ± 1.101 . All the differences are found to be small and non-significant, which establishes the validity of the formula (20).

If we now compare the differences observed in the case of the new formula of Peirce and Lord (col. 10) with those obtained in the case of the above formula (col. 12), it will be noticed that the mean value for all the cottons which is $+7.92^{**}$ per cent for the former is as low as $+0.62$ per cent for the latter. For the mature group of cotton there is a similar though smaller reduction from $+2.81^*$ to $+0.91$ per cent and for the medium mature group a reduction from $+4.80^{**}$ to -0.46 per cent while for the immature group of cottons it is reduced from the large value of $+18.9^{**}$ per cent to the small value of $+1.67$ per cent. On the whole it appears that the values for the two sets of differences approach each other in the mature cottons but the divergence between them widens with the increase of immaturity. The difference between the two formulae (13) and (20) lies, as was already pointed out, in the weighing of I , which is lower in (20) and this lower weighing has remedied the defect observed in the case of (13). That the lower weighing of I is also the more appropriate one can be seen in equations (11) and (12) which have been derived from *a priori* considerations using the data experimentally obtained. It

is, therefore, clear that the higher weighing of I in (13) is responsible for the discrepancy observed. However, if the value of I is small as in mature cottons the error caused by this factor is not considerable, but when its value is large as in immature cottons the error becomes very much indeed as was found above.

One more point may be considered and that is the difference between the old formula of Peirce and Lord (12) and the present formula (11). Actually the difference is in the values of the coefficients of H and I which are 0.75 and 0.45 respectively in the former case while they are 0.6 and 0.4 respectively in the latter case. It was already pointed out that for two out of the three cottons grown in foreign countries the mean value of the ratio for mature fibres was lower while for the immature fibres it was higher than the values of the corresponding Indian cottons. Both these facts jointly tend to increase the value of the coefficients H and I. If, therefore, the above-mentioned tendency is a general feature for all cottons of foreign origin, it may partially explain the higher values found in (12). Besides this, the lines of demarkation of the border—land between the maturity classes, being subjective in nature, may not be the same in both the methods for finding the immaturity counts. Furthermore, the difficulty involved in handling the slippery fibres, which has already been dealt with, may also be a source of error in the former case. These foregoing points may offer an explanation for the difference between (11) and (12). However, as was already pointed out, this difference is small and the error introduced by using (12) in place of (11) is not of much consequence, if some error is tolerated for immature cottons.

(c) *Mature fibre weight.* Peirce and Lord [1934] have introduced a new expression called 'standard hair-weight', which is the fibre weight of a sample of *standard* maturity. This *standard* maturity, according to them, is the maturity of a 'normal sample of well-matured cotton' 'from general experience'. In 1934 they fixed the *standard* at 64-29-7, and later in 1939 changed the *standard* to 67-26-7, while at the same time they also stated that 'growers in a field where cotton does not normally attain to full maturity of secondary thickening may find it more convenient to correct hair-weights to a lower standard of maturity, say (N-D)=30 in., while in the previous case N-D was 60. From all this it is clear that the standard has no theoretical basis. It is purely empirical and has been changed from time to time. In the case of Indian cottons also no standard could be fixed for different types of cotton. Normally the degree of maturity for *hirsutum* cottons is entirely different from that for *herbaceum* and *arboresum* cottons. Furthermore the degree of maturity differs in different localities, as also noted by Peirce and Lord. Hence it is not correct to say that 67-26-7 or for that matter any other value of fibre maturity is the standard value for Indian cottons. When there is no standard there can be no standard fibre weight. In its place we should have a quantity that is free from arbitrariness. The weight of an average mature fibre of a sample of cotton satisfies this condition. There is no arbitrariness about it and it is independent of the maturity of the sample. It can be calculated by dividing the fibre weight by the maturity coefficient and can be called the '*mature fibre weight*'. The square root of this quantity multiplied by a constant, as shown in equation (18), gives

the mean diameter of the fibre which is a genetic character of a strain of cotton. On account of these reasons the expression 'mature fibre weight' is recommended for general use in place of standard fibre weight.

SUMMARY

Maturity coefficient of a cotton is a unitary expression to signify the multiple character of fibre maturity, usually represented by the percentage of mature, half-mature and immature fibres. In order to calculate the Maturity Coefficient for Indian cottons, constants have been obtained in the present study employing a new method. For each fibre swollen in 18 per cent caustic soda solution the maturity class, the fibre diameter, D , and the lumen diameter, d , were determined. From the mean value of the expression, $\frac{D^2-d^2}{D^2}$, for the fibres falling within each maturity class and the mean fibre weight of the sample the constant for each class was derived. By studying 22 cottons covering a wide range of fibre maturity it was found that the Maturity Coefficient, M_c , is given by

$$M_c = \frac{M + 0.6H + 0.4I}{100}, \text{ where } M, H \text{ and } I \text{ represent}$$

the percentages of the mature, half-mature and immature fibres respectively in the sample. The validity of this formula was directly verified by actually weighing cm. long raw cotton fibres separated out into the three maturity classes using the polarised light technique. The present formula, however, is somewhat different from both the old and the new formulae given by Peirce and Lord and the question arises as to which of the three is the most suitable for Indian cottons. This point was clarified by comparing the value of the diameter predicted by using the M_c calculated according to a particular formula with the value actually obtained by means of the microscope. It was found that the present formula was quite satisfactory. The old formula of Peirce and Lord was also fairly satisfactory if some error was tolerated for immature cottons. Their new formula, however has been found to be definitely unsuitable for immature cottons. The cause of this defect has been analysed and it has been shown that this formula, if modified a little, would serve very satisfactorily. It has also been suggested that the expression 'mature fibre weight' is to be used in preference to standard fibre weight' as the former is free from any arbitrariness of the standard.

APPENDIX

Hygroscopicity of normal mature lint and of immature lint from 20-day old bolls of 4F Cotton

As pointed out previously the object of the study is to find out whether the moisture absorption capacity of immature fibres is the same as that of the normally mature fibres. For this purpose it is necessary to separate out the immature fibres present in a normal sample of lint. But this is not a practical proposition. Hence

completely immature fibres were obtained from 20-day old bolls. The bolls were cut open and the locks were separated and washed gently in water to remove the mucilaginous and sticky matter. The seeds were separated from one another and the fibres removed from them were dried at about 35°C. These fibres when examined under the microscope were found to possess no secondary thickening at all. The sample of normal lint from fully opened bolls was obtained later on from the same 4F plants from which the 20-day old bolls were taken.

The samples of immature lint and normal lint were next tested for their hygroscopicity. Duplicate samples of each type of lint, put in weighing bottles, were placed inside a desiccator containing sulphuric acid solution of the required strength to give a R. H. of 20 per cent, inside the chamber. Repeated weighings were made over a number of days until constant weights were noted, when the solution was diluted to give 30 per cent R. H. The lint samples were again placed inside the chamber and weighings were made until constant weights were attained. The solution was next diluted to give 40, then 50, 60, 70 and 80 per cent, R.H. and the process was repeated as before. It could not be continued to further higher humidities because fungus was formed on the immature samples of lint at 80 per cent R.H. The samples were then dried at 110°C. until constant weight was attained and from this weight the moisture regain was calculated. The results obtained are given in Table VI.

TABLE VI

Moisture regain (per cent) at various relative humidities of normal and immature 4F lint

R.H. per cent	Normal lint			Immature lint		
	I Test	II Test	Mean	I Test	II Test	Mean
Dry	0	0	0	0	0	0
20	2.79	2.75	2.77	11.97	13.08	12.52
30	3.97	3.90	3.94	14.04	15.22	14.63
40	4.76	4.66	4.71	15.77	17.08	16.42
50	5.77	5.69	5.73	18.35	19.91	19.13
60	6.35	6.33	6.34	20.23	21.87	21.05
70	7.98	7.97	7.98	25.50	24.58	25.04
80	10.23	10.23	10.23	27.31	26.12	26.72

It will be noticed that the duplicate tests agree closely for both kinds of lint and particularly so in the case of the normal lint. The values of the regain for normal lint are in conformity with those obtained by Urquhart and Williams [1924 and 1926], if it is remembered that the experimental conditions in the present work were not sensitive enough to detect hysteresis. On the other hand the regain values

for the immature lint are very much higher than the corresponding values for normal lint, being as high as 12.5 per cent even at 20 per cent R.H. The rate of increase of regain with R.H. is also considerably higher for the immature lint as can be seen in fig. 4.

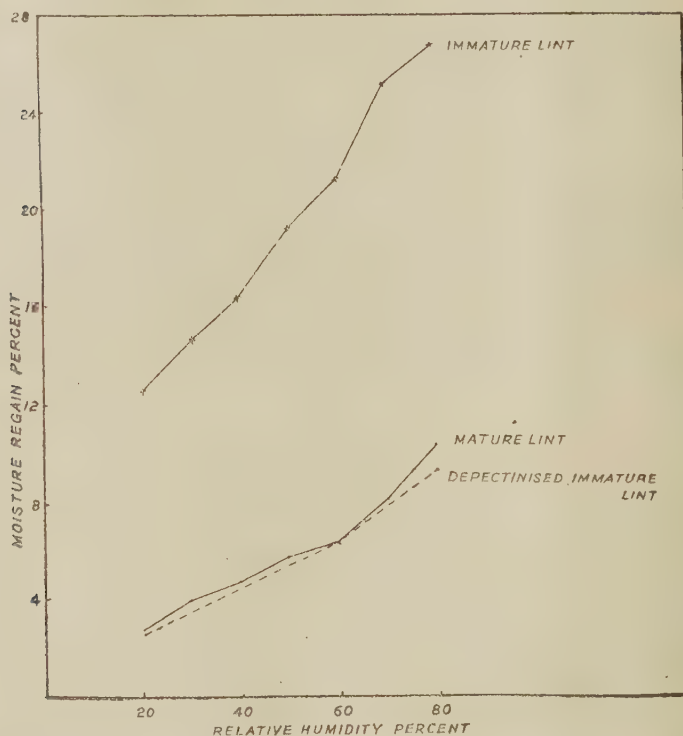


FIG. 4. Moisture regain values at different relative humidities for normal mature lint and for immature lint and depectinized immature lint

In order to find out the cause for the difference observed above and in order to see whether sterilizing the sample would overcome the fungus development, the following procedure was adopted. The four samples were each further sub-divided into two nearly equal parts. Thus eight samples, four of normal lint and four of immature lint were obtained and their dry weights were determined. Two of these samples of each type of lint were sterilized in two per cent formalin solution with a little alcohol and the remaining two samples were depectinized by the following process. Each sample was boiled for four hours in one per cent caustic soda solution, being all the while kept under a porcelain dish with perforations so that it

did not come in contact with air. The sample was then washed, soured in half per cent acetic acid and then washed over and over again until all the acid was removed. The water was squeezed out and the sample was allowed to dry in air. It was next dried in the oven at 105°C. and the dry weight was determined from which the loss sustained by the depectinization or sterilization process was obtained. The results are given in Table VII.

TABLE VII

Loss (per cent) due to depectinization or sterilization of normal and immature lint

	Description of sample	I Test	II Test	Mean
Nominal lint	Sterilized	2.4	2.4	2.4
do.	Depectinized	7.8	7.2	7.5
Immature lint	Sterilized	23.2	21.5	22.4
do.	Depectinized	53.6	54.4	54.0

It will be noticed that in the case of the normal lint the loss due to sterilization with formalin is 2.4 per cent, while that due to depectinization is about 7.5 per cent. On the other hand in the case of immature lint the sterilization process has removed as much as about 22.4 per cent while depectinization has removed a still greater amount of about 54.0 per cent. This means that the immature lint sample from 20-day old bolls contains a large quantity of material which is soluble in alcohol, formalin solution and boiling sodium hydroxide solution. This material probably may be the residue of the boll fluid filling the cavity of the 20-day old fibre.

The eight samples considered above were then conditioned at 20, 60 and 80 per cent R.H. respectively in the same manner as was done earlier and from the dry weight the moisture regain for each R.H. was calculated. The results obtained are given in Table VIII.

TABLE VIII

Moisture regain (per cent) at various relative humidities of normal and immature (sterilized and depectinized) 4F lint

R.H. per cent	Normal lint						Immature lint					
	Depectinized			Sterilized			Depectinized			Sterilized		
	I	II	Mean	I	II	Mean	I	II	Mean	I	II	Mean
20	2.28	2.32	2.30	2.42	2.46	2.44	2.48	2.50	2.49	2.79	2.92	2.86
60	5.73	5.62	5.68	6.03	6.00	6.02	6.32	6.28	6.30	8.18	8.40	8.29
80	8.44	8.32	8.38	9.12	8.77	8.94	9.40	9.35	9.38	13.13	13.15	13.16

It will be observed that the moisture regain of immature lint samples has been reduced considerably by depectinization. It has been brought down practically to the same level as that shown by normal lint. Even washing with formalin solution has been able to effect a considerable change. What were originally about

13, 21 and 27 per cent respectively for 20, 60 and 80 per cent R.H. have been reduced to 3, 8 and 13 per cent respectively. Which means that the conspicuous hygroscopicity of 20-day old lint is due to the presence of material which is removable to a large extent even by washing with formalin solution. What these substances are and how they are present in the fibres require to be determined but they are not pertinent to the present enquiry.

Incidentally it will be noted that the values recorded in Table VIII for depectinized lint, viz., 2.30, 5.66 and 8.38 are somewhat smaller than the corresponding values recorded in Table VI for normal lint, viz., 2.75, 6.33 and 10.23. Apart from depectinization causes, the differences observed are due to the fact that the former figures were obtained for samples of lint dried in the oven a number of times, where as the latter figures were obtained for raw lint samples.

From the above it is clear that completely immature fibres taken from 20-day old bolls show hygroscopic properties different from those of normal lint, which may be due to the presence of the residue of the boll fluid in the former case. But in a boll that opens normally there is no such fluid and therefore there is no chance of the presence of such residue inside the immature fibres that are found in normal lint. Moreover these immature fibres are not completely devoid of secondary thickening as 20-day old fibres are. Hence it can be expected that the difference in hygroscopicity of the immature lint normally found in a sample of lint and that of the mature lint is not as large as was found above. Further detailed study is necessary to determine the extent of the differences. For such an enquiry the difficulties involved in the separation of the immature fibres from the normal lint has already been pointed out. A new method of obtaining the immature sample of lint or a different method of approach is called for. However, whatever may be the value of the difference in the hygroscopicities of the immature and mature lint it is hoped that it does not affect the values of the constants derived in the present study, as indirect verification has pronounced a satisfactory verdict.

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STUDIES ON THE PHYSIOLOGY OF GROWTH AND DEVELOPMENT OF *mung** (*phaseolus aureus* Roxb.)

(a) EFFECT OF THE TIME OF SOWING, (b) VERNALIZATION AND PHOTOPERIODISM

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(With Plates II, III and IV and twentytwo text—figures.)

NO work has been done on the fundamental aspects of the physiology of growth and development of the plant of *Mung* (*Phaseolus aureus* Roxb.) with reference to various external factors.

Any investigation on the physiology of nutrition or on the breeding, or on disease resistance, should be based on the optimum time for sowing the plant and for these studies it is extremely important to know the relative influence of the climatic factors on the growth and development of the plant.

To understand the nature of the responses of the plant to the different climatic factors, this investigation on the effect of different times of sowing on the growth and development of the plant was undertaken. In addition, the effect of pre-sowing low-temperature treatment of seeds, well known as vernalization, and the effect of daily light period known as photoperiodism respectively, were also investigated.

EXPERIMENTAL PROCEDURE

Two strains of *Mung* (1) I.P. 28 (seeds obtained through the courtesy of the Imperial Agricultural Research Institute), and (2) *Sona Mung* (the recommended variety for Bengal, seeds obtained through the courtesy of the Department of Agriculture, Government of Bengal) have been used in this investigation. Seeds, selected to be of uniform size as far as possible, were sown in earthen pots of 13 in. height and 14 in. diameter at the top in ordinary garden soil without the addition of any manure at the experimental pot culture garden of the Presidency College, Calcutta.

* This plant commonly known in India as *Mung*, *Green gram*, *Golden gram*, *Sona Mung*, etc., has been long known botanically as *Phaseolus radiatus* Auct. non Linn. Piper and Morse in their interesting paper on 'Five oriental species of Beans'—U.S. Dept. of Agriculture Bull. No. 119 (1914) have pointed out that Linnaeus's type specimen of *Phaseolus radiatus* represents a plant which is not that of our common *Mung*. Therefore, the name *Phaseolus radiatus* Linn. can not be applied to that plant. The next available name, i.e., *Phaseolus aureus* Roxb. has therefore been accepted as the valid name by Piper and Morse for this plant. We are grateful to Dr Chatterjee, Systematic Botanist, Indian Agricultural Institute, New Delhi, for drawing our attention to Piper and Morse's paper.

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For each pot, twelve seeds were sown in the afternoon, and when the seedlings appeared, four plants were kept equidistant from each other as far as practicable. Five pots were used for each treatment all the pots having the same type of soil. They were watered regularly and uniformly in the afternoon except on rainy days.

There were six sowings at an interval of 15 days commencing from 15 August 1945, viz., 15 August, 30 August, 14 September, 29 September, 14 October, 29 October, and six additional sowings for *Mung* I.P. 28 at an interval of 30 days from 26 October 1944, viz., 26 October, 25 November, 25 December, 24 January (1945), 23 February and 25 March.

PHOTOPERIODISM

Sown on 14 September, 1945, one set of 20 plants was exposed to a short photoperiod of 10 hours, and a second similar set to a long photoperiod of 14 hours per day. In short photoperiod treatment the pots were taken to a ventilated dark room in the afternoon and kept till dusk, after which they were brought back to the open field. The hours of darkness necessary to complete 10 hours of daily light period were adjusted and the pots taken to the dark room at the desired time. The additional period of light for the long photoperiod was given in a ventilated room by exposing the plants to an electric light from 200 C.P. from a distance of one metre beginning from dusk, the period being suitably adjusted to make the daily light exposure period 14 hours.

VERNALIZATION

Sown on the 14 September 1945.

For each variety, seeds, were exposed to a temperature varying from 2°C. to 4°C. in a refrigerator for a period of 10 days before sowing. 100 seeds of almost uniform size, for each variety, were soaked in water for 5 hours. It was found in a preliminary experiment that the time taken for the seed coat to burst, when soaked in water, was 5 hours 45 minutes.

Seeds were kept in the refrigerator at a temperature of 2°C. to 4°C. during the period of treatment from 4 September to the 14 September when they were sown in pots, five pots with twenty plants being used for this treatment as usual.

An experiment with 45 days of treatment of the seeds in a similar manner in September-October, showed that these seeds failed to germinate.

Developmental changes of the vegetative phase of the plants were followed by taking the following readings at intervals of 15 days.

Height. This was measured by centimetre scale from the level of the soil to the tip of the stem.

Number of nodes. All nodes including the cotyledonary node and excluding the undifferentiated nodes at the tip of the axis, were counted.

Number of leaves. All the leaves which unfolded their leaf-lamina were counted including the leaves produced on the branches, but excluding the cotyledonary leaves.

Number of branches. Number of branches from the main axis with at least one leaf, was counted.

The changes of the reproductive phase were followed by noting the following individually for each plant.

Budding. The date of the initiation of the first visible flower bud.

Flowering. The date of the opening of the first flower.

Fruiting. The date of the initiation of the first fruit.

The reading in each case was taken separately for each of the 20 plants for each treatment and the results recorded as mean of the 20 plants. In a few cases, *viz.*, the 25 December 1944, 24 January 1945, and 25 March 1945, sowings of I.P. 28, due to the premature death of some of the plants, it was not possible to have the mean readings for 20 plants especially in the records during the reproductive phase. In these cases the mean records of the different characters studied were for those plants which were living at that time without taking into consideration the dead ones.

EXPERIMENTAL RESULTS

Germination. The time—in days—taken for the germination of the seeds of the two varieties are given below :

Dates of sowing		26 October 1944	25 November 1944	25 December 1944	24 January 1945	23 February 1945	25 March 1945	15 August 1945	30 August 1945	14 September 1945	29 September 1945	14 October 1945	29 October 1945
Variety	I.P. 28 . . .	3	9	6	7	5	7	2	2	3	3	3	4
	<i>Sona Mung</i> . .	..	..	..	..	..	..	2	2	3	3	3	4

It is seen that germination is delayed during the colder months, and between August and October there is a general agreement between the two varieties in their times of germination.

Time of sowing. The total heights reached, the number of nodes, leaves, and branches at the fruiting stage, and the times of the initiation of the flower buds, opening of flower and the initiation of fruits are tabulated in the Table IA for I.P. 28, and IB for *Sona Mung* and represented graphically in Figs IA and Ia for I.P. 28, and IB and Ib for *Sona Mung*.

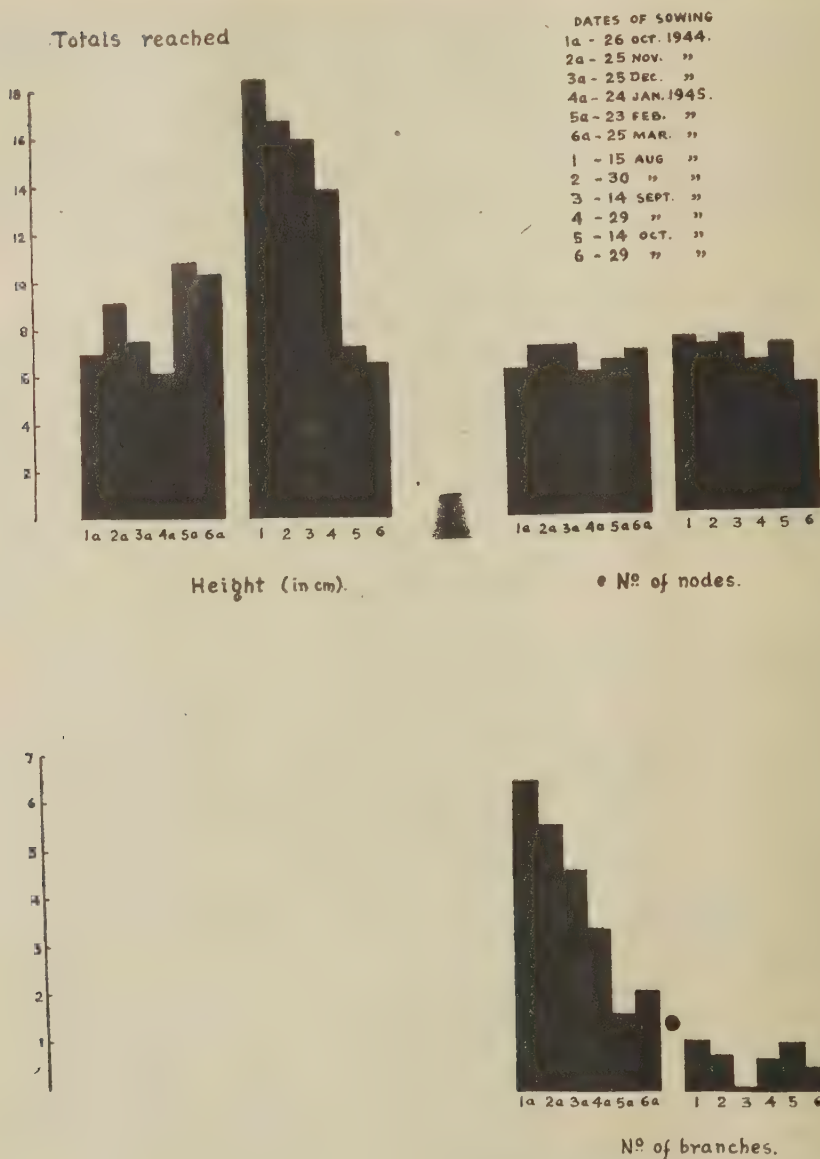


FIG. 1A (I.P. 28)

FIG. 1 A. Graphical representation of total heights, number of nodes, and number of branches

DATES OF SOWING

1a - 26 OCT. 1944.

2a - 25 NOV. "

3a - 25 DEC. "

4a - 24 JAN. 1945.

5a - 23 FEB. "

6a - 25 MAR. "

1 - 15 AUG. "

2 - 30 " "

3 - 14 SEPT. "

4 - 29 " "

5 - 14 OCT. "

6 - 29 " "

VEGETATIVE PERIOD - BUDDING

BUDDING - FLOWERING

FLOWERING - FRUITING

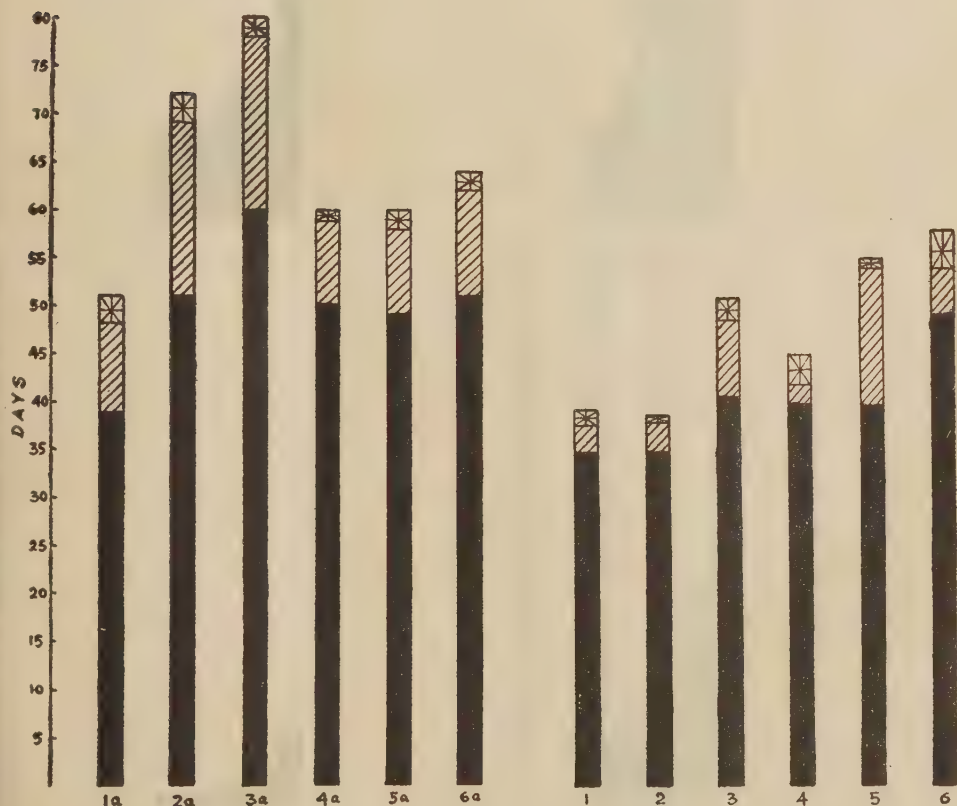


FIG. 1a. (I.P.28)

FIG. 1 A. Graphical representation of budding, flowering and fruiting

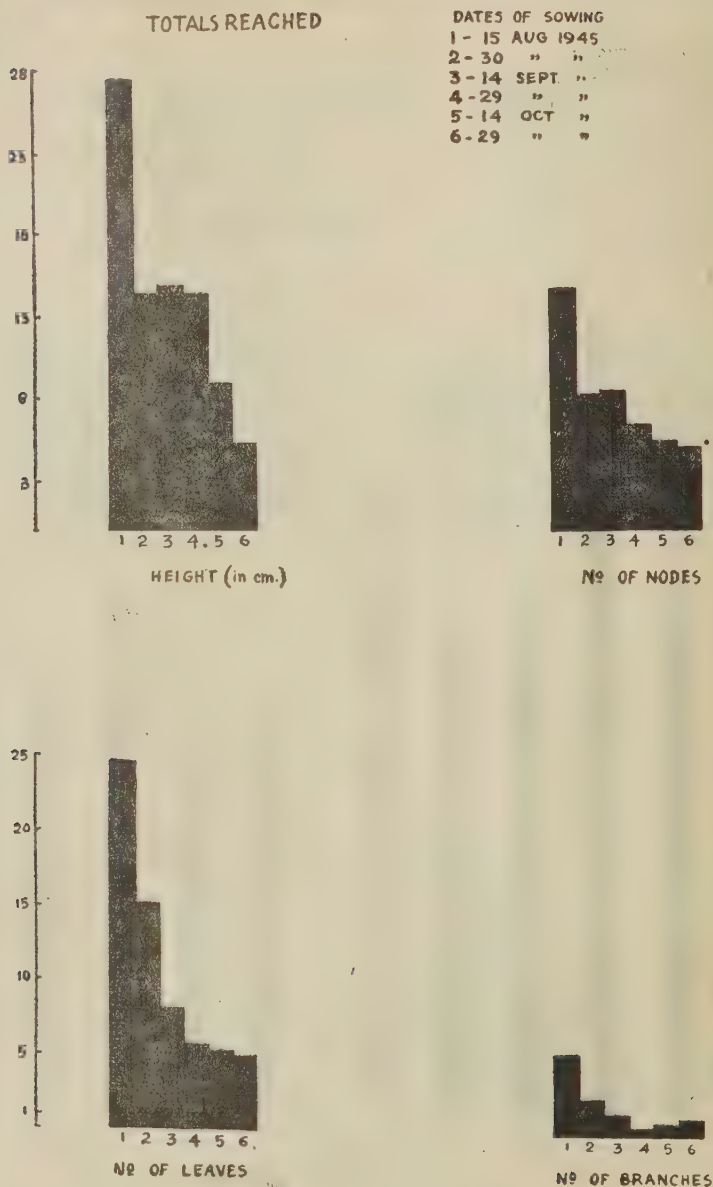


FIG. 1B (SONA MUNG)

FIG. 1 B. Graphical representation of total heights, number of nodes, leaves and branches



FIG. 1b (SONA MUNG)

Fig. I B. Graphical representation of budding, flowering and fruiting

TABLE I

Budding, flowering and fruiting in days and their dates and total height, number of nodes, number of leaves and number of branches reached at the fruiting stage

Dates of sowing	Totals reached				Dates of			Days after sowing			Difference in days between	
	Height	Number of nodes	Number of leaves	Number of branches	Budding	Flowering	Fruiting	Budding	Flowering	Fruiting	Budding and flowering	Flowering and fruiting
TABLE I-A (Mung IP-28)												
26 October 1944	6.88	6.21	3.00*	6.47	4 December	13 December	16 December	39	48	51	9	3
25 November 1944	9.11	7.21	5.73*	5.53	15 January	2 February	5 February	51	69	72	18	3
25 December 1944	7.54	7.20	3.00*	4.60	23 February	13 March	15 March	60	78	80	18	2
24 January 1945	6.15	6.00	6.60	3.40	15 March	24 March	25 March	50	59	60	9	1
23 February 1945	10.69	6.50	7.89	1.61	13 April	22 April	24 April	49	58	60	9	2
25 March 1945	10.22	6.88	9.77	2.11	15 May	26 May	28 May	51	62	64	11	1
15 August 1945	18.35	7.33	7.25	1.05	19 September	22 September	23 September	34.80	37.57	39.32	2.77	1.75
30 August 1945	16.66	7.10	6.15	0.73	4 October	7 October	8 October	35.11	37.85	38.55	2.84	0.60

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GROWTH AND DEVELOPMENT OF *MUNG*TABLE I-B
(*Sona Mung*)

14 September 1945	15.87	7.37	3.84*	0.05	24 October	2 November	4 November	40.45	48.55	50.72	8.10	2.17
29 September 1945	13.81	6.37	4.37	0.46	8 November	10 November	13 November	39.70	41.75	45.00	2.05	3.25
14 October 1945	7.19	7.10	6.55	0.95	23 November	7 December	8 December	39.82	54.50	55.00	14.68	0.50
29 October 1945	6.47	5.42	6.26	0.42	17 December	22 December	28 December	49.41	54.00	58.00	4.59	4.00
15 August 1945	27.25	14.01	24.72	5.50	20 October	27 October	1 November	65.50	72.80	77.70	7.30	4.90
30 August 1945	14.36	8.15	15.29	12.55	23 October	2 November	4 November	54.35	64.68	67.21	10.33	2.53
14 September 1945	14.53	8.40	8.20	11.55	30 October	6 November	9 November	46.10	52.84	55.47	6.71	2.63
29 September 1945	14.35	6.30	5.85	10.56	3 November	10 November	12 November	31.85	41.77	43.87	6.92	2.10
14 October 1945	8.98	5.25	5.35	0.95	15 November	22 November	24 November	31.00	38.03	40.55	7.03	1.92
29 October 1945	5.28	5.00	5.10	1.25	25 November	2 December	5 December	27.00	34.22	37.00	7.22	2.78

* The total number of leaves decreased at the final observation as many of them were shed before fruiting.

In the following tables the growth in height, the number of nodes, leaves and branches are given for every 15 days. [It should be noted that the measurements for the vegetative growth were discontinued after fruiting, the period up to which the readings were taken.]

The heights reached and the increase in height for every 15 days, and the average rate of increase in height per day calculated by dividing the total height reached by the time taken to attain it, are tabulated in Tables IIA and IIB and the data are graphically represented in Figs. IIA and IIB for I P-28 and *Sona Mung* respectively.

Dates of sowing	Days after sowing—height						Increment in heights between					Average rate of increase per day
	15	30	45	60	75	90	15 to 30th day	30 to 45th day	45 to 60th day	60 to 75th day	75 to 90th day	

TABLE II-A

(*Mung IP-28*)

26 October 1944	3-53	4-73	6-13	6-88	..	..	1-20	1-40	0-75	..	..	0-11
25 November 1944	2-35	2-74	3-80	6-58	9-11	..	0-39	1-06	2-78	2-53	..	0-12
25 December 1944	1-58	2-41	2-75	3-31	4-50	7-54	0-83	0-34	0-56	1-19	3-04	0-08
24 January 1945	1-47	2-42	3-04	6-15	..	..	0-95	0-62	3-11	..	..	0-10
23 February 1945	2-59	4-23	8-67	10-69	..	..	1-64	4-44	2-02	..	..	0-18
25 March 1945	1-53	3-06	5-23	10-22	..	..	2-43	1-27	4-99	..	..	0-17
15 August 1945	10-85	17-75	18-35	..	..	..	6-90	0-60	..	..	..	0-41
30 August 1945	8-62	15-11	16-66	..	..	..	6-49	1-55	..	..	..	0-37

Dates of sowing	Days after sowing—after						Increment in heights between					Average rate of increase per day
	15	30	45	60	75	90	15 to 30th day	30 to 45th day	45 to 60th day	60 to 75th day	75 to 90th day	

TABLE II-A—*contd.**(Mung IP-28)*

14 September 1945	5.83	12.26	14.95	15.87	..	..	6.43	2.69	0.92	..	..	0.26
29 September 1945	5.36	11.75	13.81	..	..	..	6.39	2.06	..	..	..	0.31
14 October 1945	5.13	6.21	7.11	7.19	..	..	1.08	0.90	0.08	..	..	0.12
29 October	3.98	4.74	6.16	6.47	..	..	0.76	1.42	0.31	..	..	0.11

TABLE II-B

(Sona Mung)

15 August 1945	7.45	11.98	23.93	26.26	27.25	..	4.53	11.95	2.33	0.99	..	0.3
30 August 1945	7.10	12.00	12.75	13.10	14.36	..	4.90	0.75	0.35	1.26	..	0.19
14 September 1945	6.85	12.93	13.28	14.53	..	..	6.08	0.35	1.25	..	..	0.24
29 September 1945	6.63	12.23	14.35	..	..	..	5.60	2.12	..	..	..	0.32
14 October 1945	6.53	7.57	8.98	..	..	..	1.04	1.41	..	..	..	0.20
29 October 1945	3.50	5.10	5.23	..	..	..	1.60	0.18	1.26	..	..	0.12

The number of nodes, the increase in the number every 15 days, and the average daily increase in the number of nodes are tabulated in Tables IIIA and IIIB, and represented graphically in Figs. IIIA and IIIB for IP-28 and *Sona Mung* respectively.

DATES OF SOWING.

1a	-	26 Oct.	1944
2a	-	25 Nov.	"
3a	-	25 Dec.	"
4a	-	24 Jan	1945
5a	-	23 Feb.	"
6a	-	25 Mar.	"
1	-	15 Aug.	"
2	-	30 "	"
3	-	14 Sept.	"
4	-	29 "	"
5	-	14 Oct.	"
6	-	29 "	"

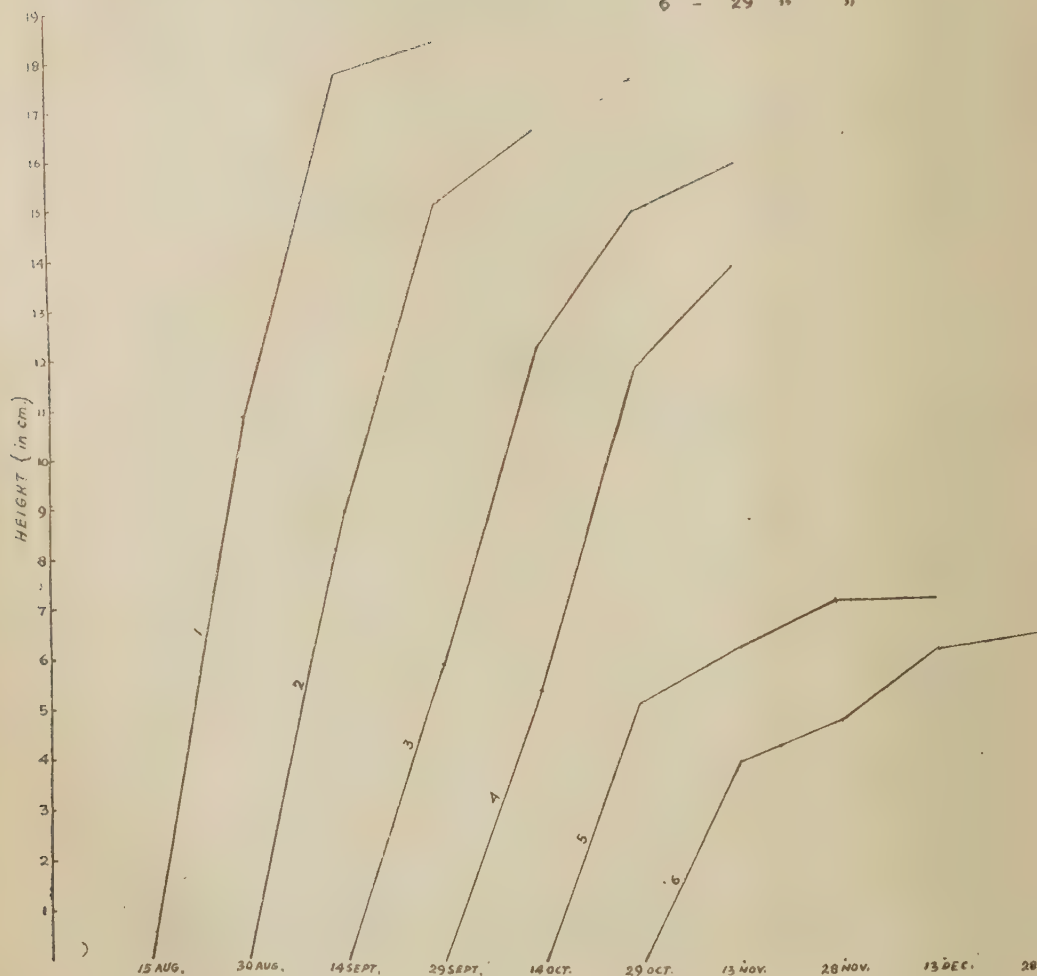


FIG- II A

FIG. IIA. (I. P-28). Graphical representation of the number of nodes, increase in number after every 15 day and average daily increase in the number of nodes.

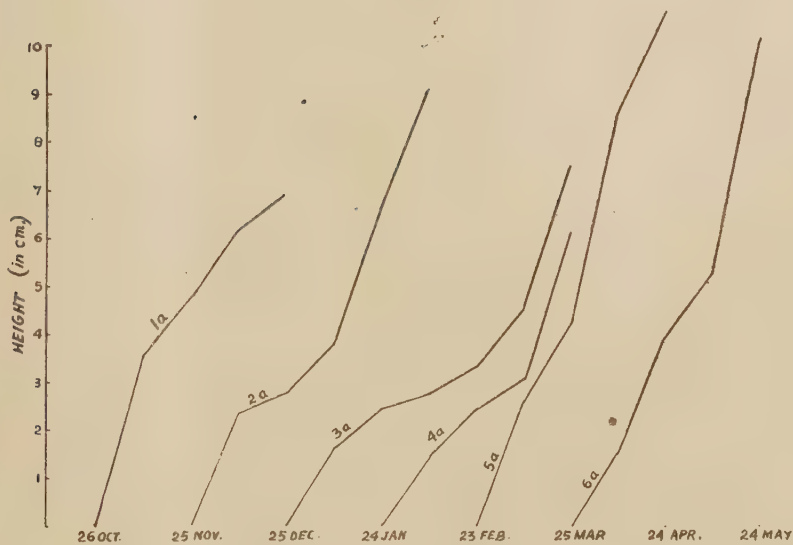
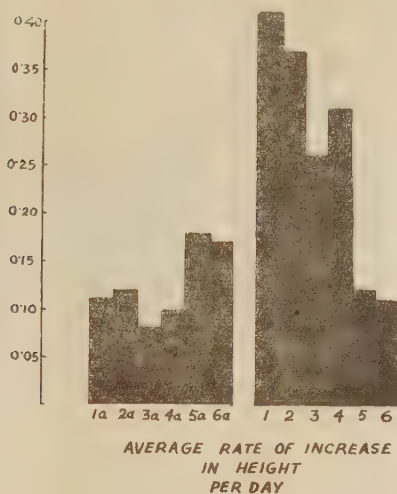


FIG IIA (I. P. 28)

FIG. IIA. Graphical representation of the number of nodes, increase in number after every 15 days and average daily increase in the number of nodes.

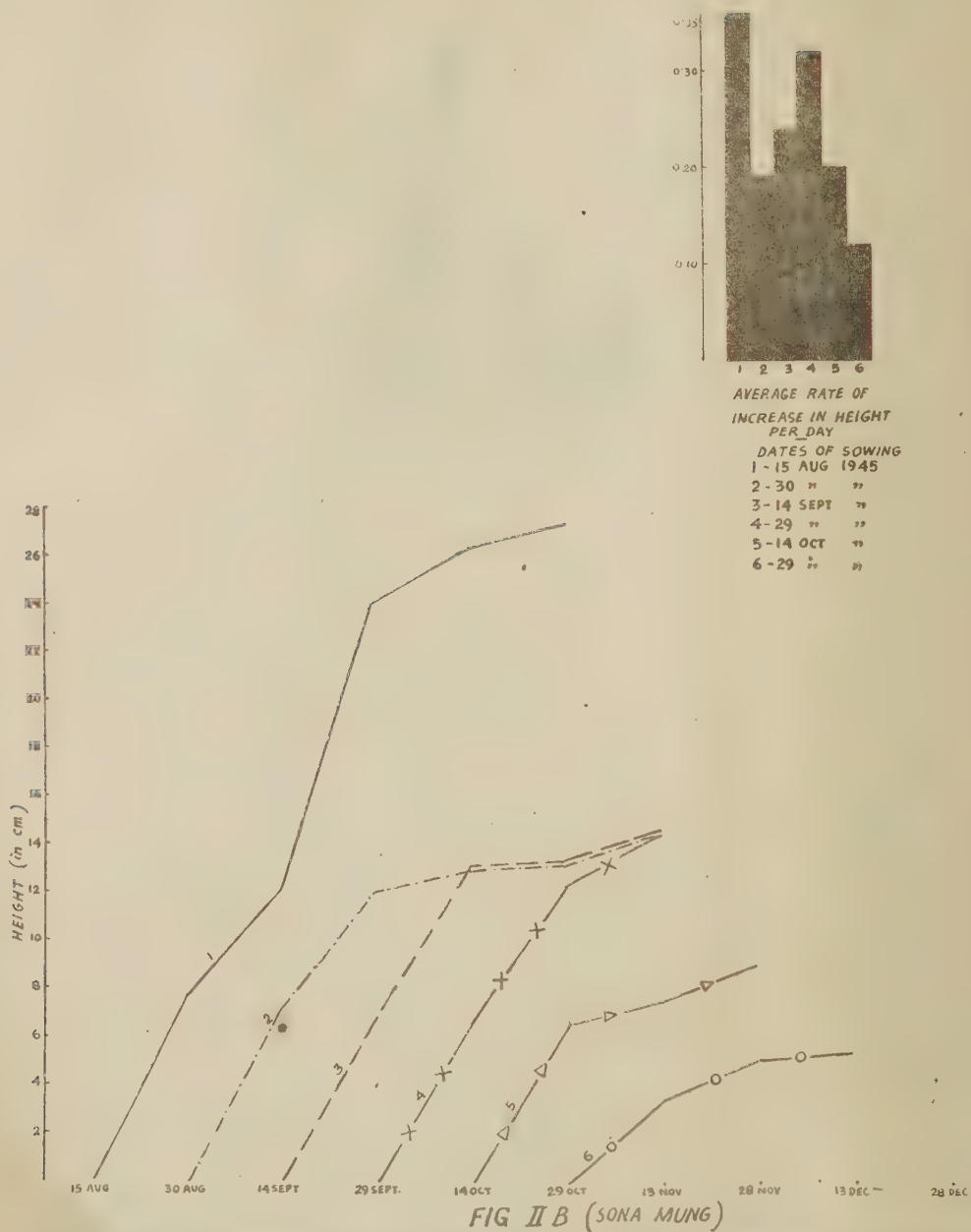


FIG. II B. Graphical representation of the number of nodes, increase in number after every 15 days, and average daily increase in the number of nodes.

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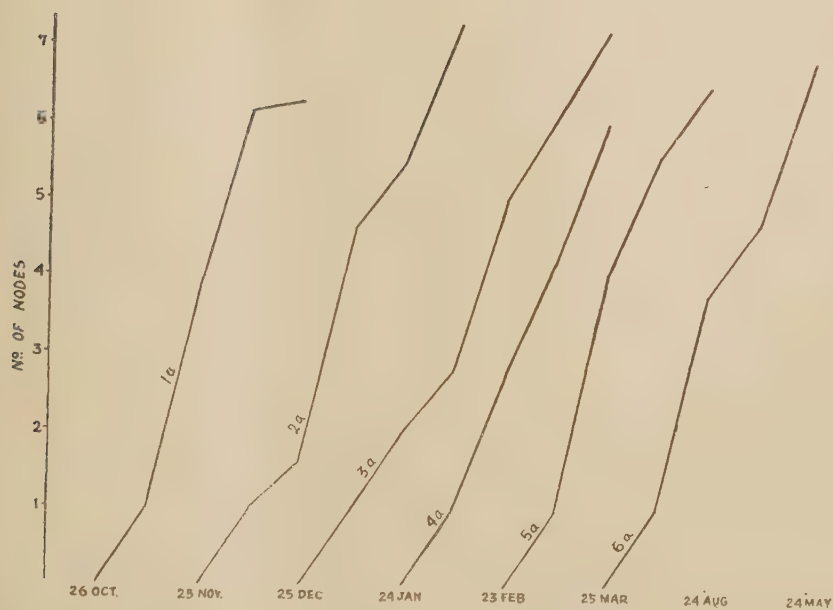
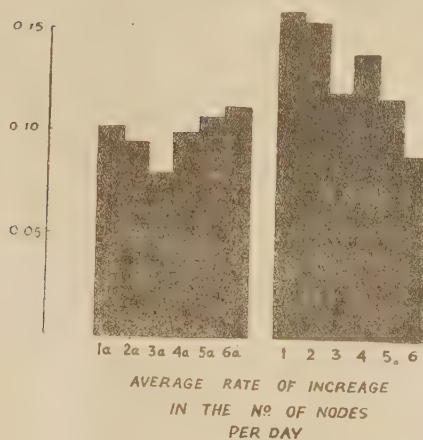


FIG III A (I.P.28)

Fig. IIIA. Graphical representation of the number of nodes, increase in number after every 15 days and average daily increase in the number of nodes.

DATES OF SOWING

1a -	26 OCT.	1944
2a -	25 NOV.	"
3a -	25 DEC.	"
4a -	24 JAN.	1945
5a -	23 FEB.	"
6a -	25 MAR.	"
1 -	15 AUG.	"
2 -	30 "	"
3 -	14 SEPT.	"
4 -	29 "	"
5 -	14 OCT.	"
6 -	29 "	"

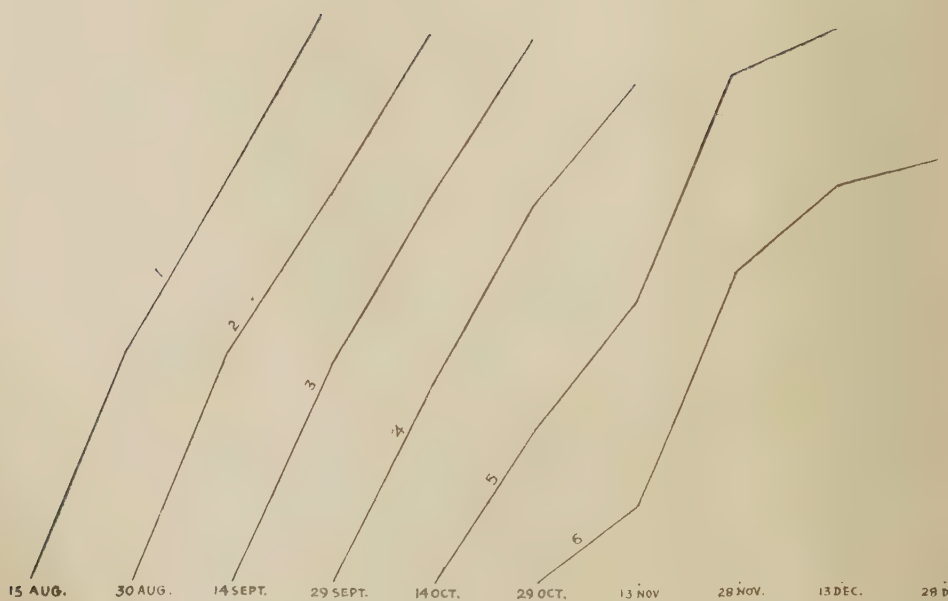


FIG. IIIA (I.P.28)

FIG. IIIA. Graphical representation of the number of nodes, increase in number after every 15 days and average daily increase in the number of nodes.

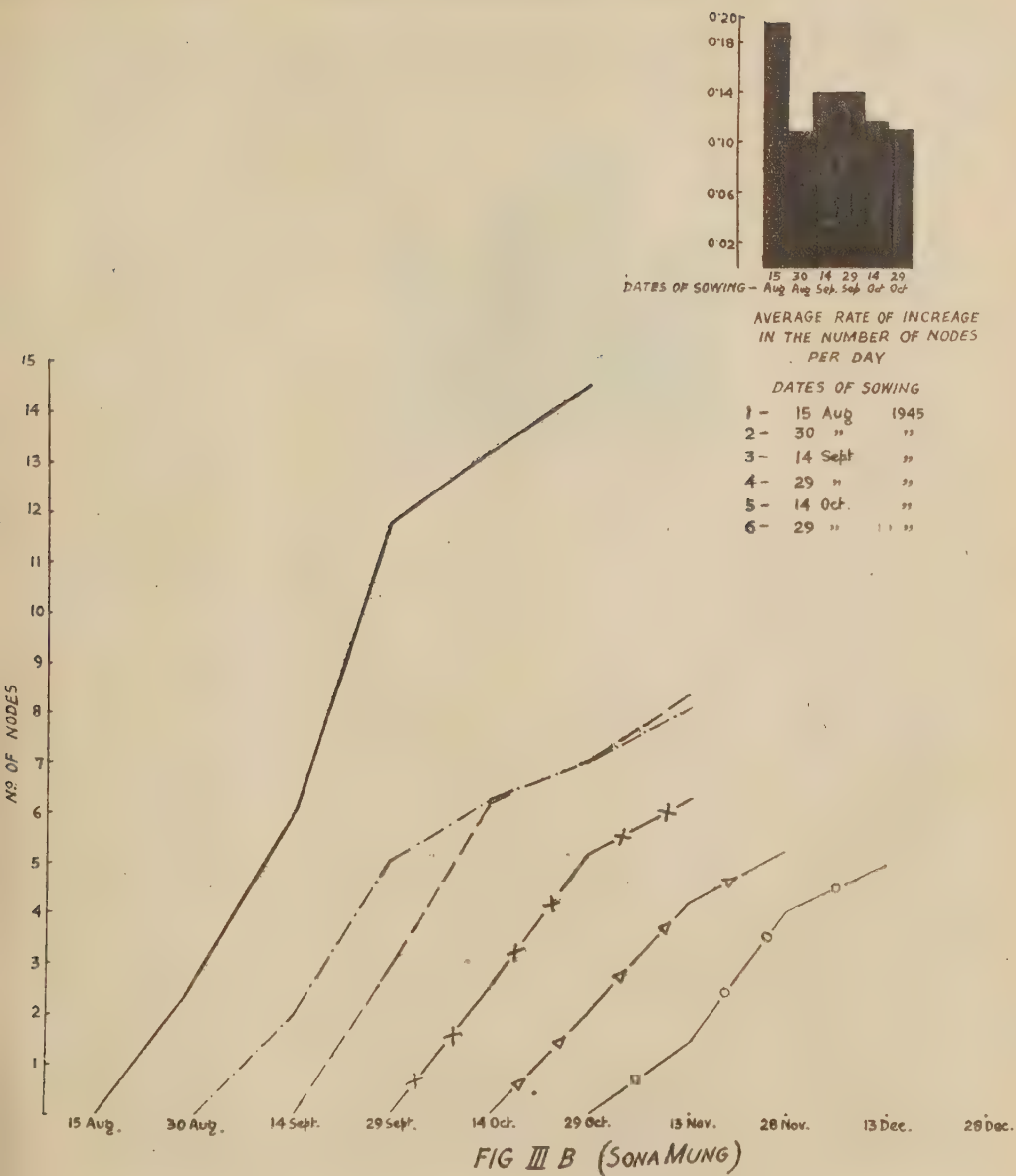


FIG. IIIB. Graphical representation of the number of nodes, increase in number after every 15 days and average daily increase in the number of nodes.

Dates of sowing	Number of nodes Days after sowing					Increase in the number of nodes between					Average rate of increase per day
	1	30	45	60	75	90	15th- 30th day	30th- 45th day	45th- 60th day	60th- 75th day	75th- 90th day

TABLE III-A
(*Mung I.P. 28*)

26 October 1944	1.00	3.89	6.11	6.21	..	..	2.89	2.22	0.10	..	0.103
25 November 1944	1.00	1.63	4.58	5.47	7.21	..	0.63	2.95	0.39	1.74	0.096
25 December 1944	1.00	2.00	2.80	5.00	..	7.20	1.00	0.80	2.20	..	0.080
24 January 1945	1.00	2.75	4.18	6.00	..	..	1.75	1.43	1.82	..	0.100
23 February 1945	1.00	4.05	5.55	6.50	..	..	3.05	1.50	0.95	..	0.108
25 March 1945	1.00	3.83	4.71	6.88	..	..	2.83	0.83	2.17	..	0.113
15 August 1945	3.00	5.10	7.33	..	..	..	2.10	2.23	..	..	0.162
30 August 1945	3.00	5.00	7.10	..	..	..	2.00	2.1	..	..	0.157
14 September 1945	2.80	5.00	7.00	7.37	..	..	2.20	2.00	0.37	..	0.122
29 September 1945	2.55	4.90	6.37	..	..	..	2.35	1.47	..	..	0.141
14 October 1945	2.00	3.60	6.55	7.10	..	..	1.60	2.95	0.55	..	0.118
29 October 1945	1.00	4.00	5.10	5.42	..	..	3.00	1.10	0.32	..	0.090

TABLE III-B
(*Sona Mung*)

15 August 1945	2.65	6.10	11.80	13.30	14.61	..	3.45	5.70	1.59	1.31	0.194
30 August 1945	2.00	5.05	6.30	7.10	8.15	..	3.03	1.27	0.30	1.05	0.108
14 September 1945	3.00	6.25	7.10	8.40	..	..	3.25	0.85	1.30	..	0.140
29 September 1945	2.50	5.20	6.30	..	..	..	2.70	1.10	..	..	0.140
14 October 1945	2.00	4.20	5.25	..	..	..	2.20	1.05	..	..	0.116
29 October 1945	1.45	4.05	5.00	..	..	..	2.80	0.95	1.15	..	0.111

The number of leaves on the plant, increase in the number every 15 days and the average daily rate of increase in the number (calculated by dividing the highest number reached by the time required to attain it) are tabulated in Tables IV-A and IV-B and represented graphically in Figs. IV-A and IV-B for I.P. 28 and *Sona Mung* respectively.

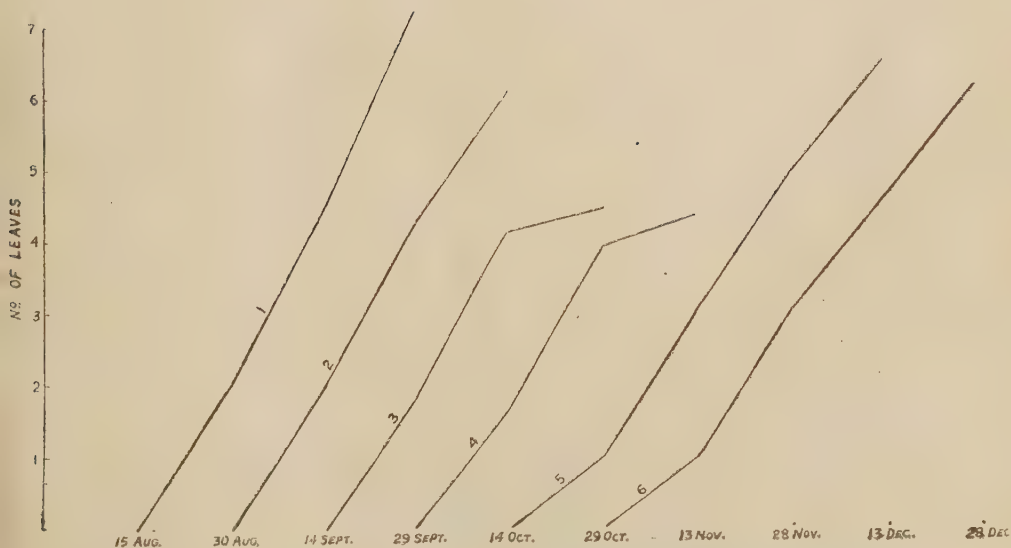
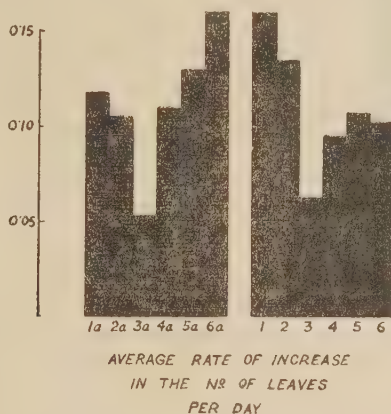


FIG. IV A. (I.P. 28)

FIG. IV A. Graphical representation of the number of leaves on the plant, increase in the number every 15 days and average daily rate of increase in number.

DATES OF SOWING

1a -	26 Oct.	1944
2a -	25 Nov.	"
3a -	25 Dec.	"
4a -	24 Jan.	1945
5a -	23 Feb.	"
6a -	25 Mar.	"
1 -	15 Aug.	"
2 -	30 "	"
3 -	14 Sept.	"
4 -	29 "	"
5 -	14 Oct.	"
6 -	29 "	"

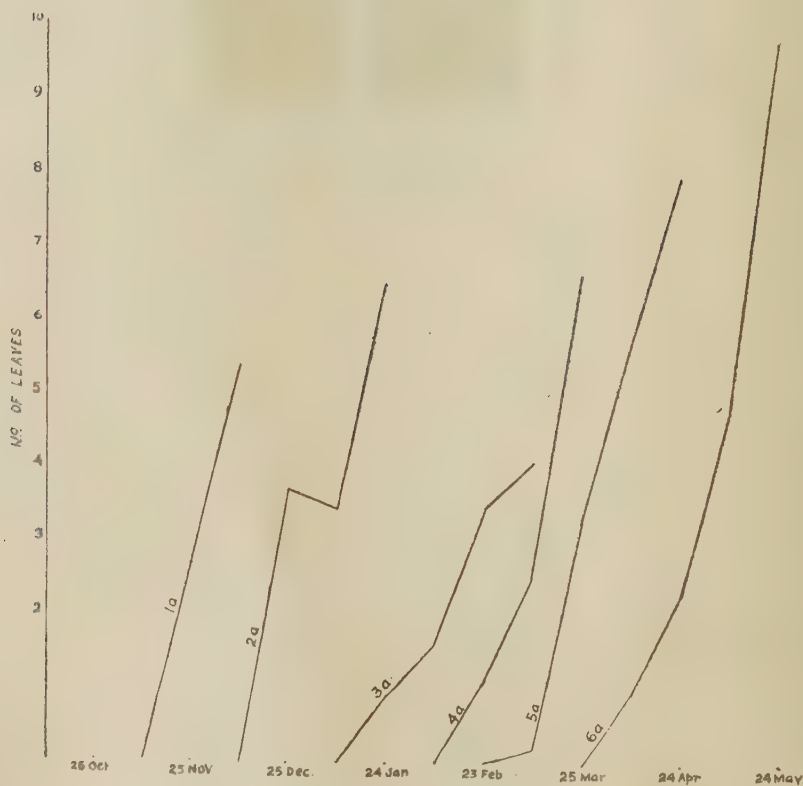


FIG IV A. (I.P.28)

Fig. IV A. Graphical representation of the number of leaves on the plant, increase in the number every 15 days and average daily rate of increase.

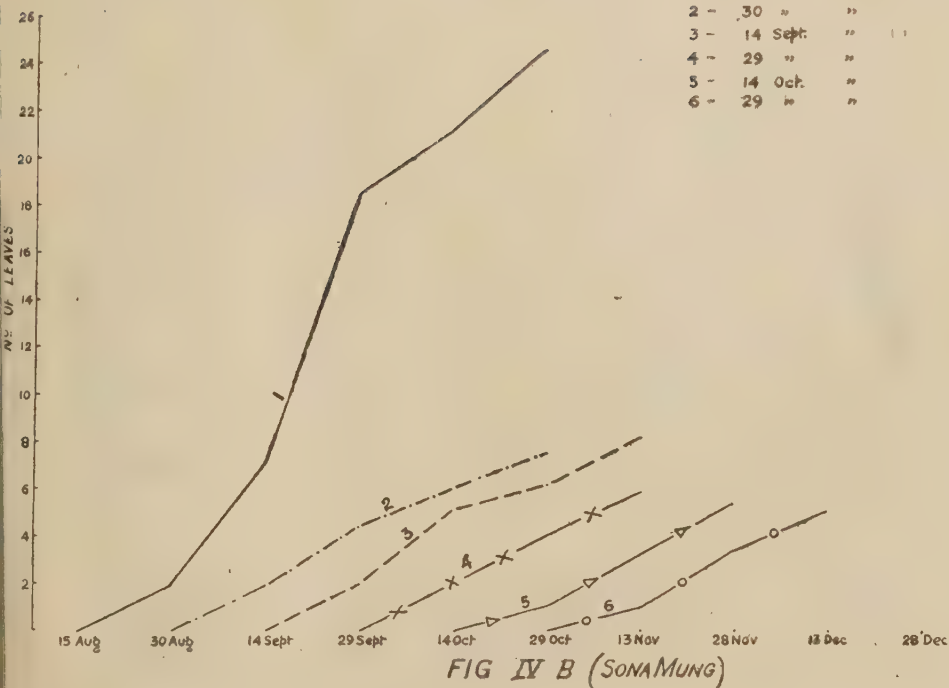
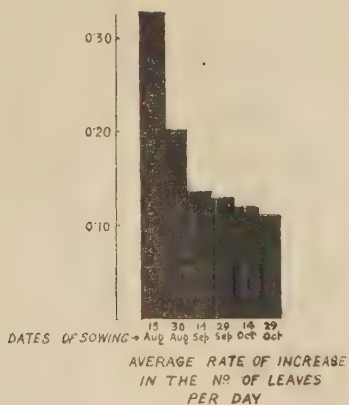


FIG. IV B. Graphical representation of the number of leaves on the plants increase in the number every 15 days and average daily rate of increase.

Dates of sowing	Number of leaves on the plants Days after sowing						Increase in the number of leaves between					Average rate of increase per day
	15	30	45	60	75	90	15th to 30th	30th to 45th	45th to 60th	60th to 75th	75th to 90th	
26 October 1944	..	2.74	5.32	3.00	..	..	2.74	2.58	-2.32 *(Decrease)	..	..	0.118
25 November 1944	..	3.68	3.37	6.42	5.73	..	3.68	-0.31 *(Decrease)	3.05	-0.49 *(Decrease)	..	0.107
25 December 1944	..	0.90	1.60	3.44	4.07	3.00	0.90	0.70	1.84	0.63	-1.07 *(Decrease)	0.054
24 January 1945	..	1.10	2.50	6.60	..	..	1.10	1.40	4.10	..	..	0.110
23 February 1945	0.20	3.30	5.65	7.89	..	..	3.10	2.35	2.24	..	..	0.131
25 March 1945	1.00	2.33	4.85	9.77	..	..	1.33	2.52	4.92	..	..	0.162
15 August 1945	2.00	4.45	7.25	..	..	..	2.45	2.86	..	..	..	0.161
30 August 1945	2.00	4.30	6.15	..	..	..	2.30	1.35	..	..	..	0.136
14 September 1945	1.85	4.10	4.45	3.84	..	..	2.25	0.35	-0.31 *(Decrease)	..	..	0.064
29 September 1945	1.66	3.90	4.37	..	..	..	2.24	0.47	..	..	..	..
14 October 1945	1.00	3.05	4.94	6.55	..	..	2.05	1.80	1.61	..	..	0.109
29 October 1945	1.00	3.04	4.66	6.26	..	..	2.04	1.62	1.60	..	..	0.104

TABLE IV-A
(*Mung I.P. 28*)TABLE IV-B
(*Sona Mung*)

15 August 1945	1-90	7-00	18-45	21-21	24-72	..	5-10	11-45	2-76	3-51	..	0-329
30 August 1945	1-85	4-80	6-00	7-50	15-20	..	2-45	1-70	1-50	7-70	..	0-220
14 September 1945	2-00	5-10	6-15	8-20	..	..	3-10	1-05	2-05	..	..	0-136
29 September 1945	2-00	4-00	5-85	..	..	..	2-00	2-85	..	..	..	0-138
14 October 1945	1-00	3-20	5-85	..	..	..	2-20	2-15	..	..	..	0-118
29 October 1945	1-00	3-40	5-10	..	..	..	2-40	1-70	1-15	..	..	0-118

* The decrease in the number of leaves were due to the shedding of some of them

The number of branches and the increase in number every 15 days are tabulated in Tables V-A and V-B for I.P. 28 and *Sona Mung* respectively.

[New branches were produced even after fruit formation, but there are no records after 'fruiting'.]

Dates of sowing	Number of branches Days after sowing					Increase in the number of branches between					
	15	30	45	60	75	90	15th to 30th day	30th to 45th day	45th to 60th day	60th to 75th day	75th to 90th day
TABLE V-A (<i>Mung I.P. 28</i>)											
28 October 1944	3-00	6-47	..	..	..	3-00	3-47	..	..
25 November 1944	..	1-21	1-85	4-03	5-53	..	1-21	0-41	3-03	0-85	..
25 December 1944	1-61	2-54	4-60	..	..	1-61	0-93	2-00
24 January 1945	3-40	..	..	..	..	3-40	..	..
23 February 1945	0-30	1-61	..	..	..	0-30	1-31	..	..
26 March 1945	2-11	..	..	..	..	2-11	..	..
15 August 1945	..	0-05	1-05	..	..	..	0-05	1-00	..	..	..
30 August 1945	0-73	..	..	..	..	0-73	..	..	..
14 September 1945	0-05	..	..	..	..	0-05	..	..
29 September 1945	0-66	..	..	..	..	0-66	..	..	..
14 October 1945	0-28	0-95	..	..	..	0-28	0-67	..	..
29 October 1945	0-16	0-42	..	..	..	0-16	0-26	..	..

TABLE V-B (<i>Sona Mung</i>)											
15 August 1945	..	1-45	3-95	5-10	5-50	..	1-45	2-50	1-15	0-40	..
30 August 1945	..	..	..	1-05	2-55	..	..	1-05	1-05	1-50	..
14 September 1945	..	..	0-10	1-55	..	..	..	0-10	1-45	..	..
29 September 1945	..	..	0-66	..	..	..	..	0-56	..	..	..
14 October 1945	..	..	0-95	..	..	..	..	0-95	..	..	..
29 October 1945	..	0-35	1-25	..	..	..	0-35	0-90	0-30	..	..

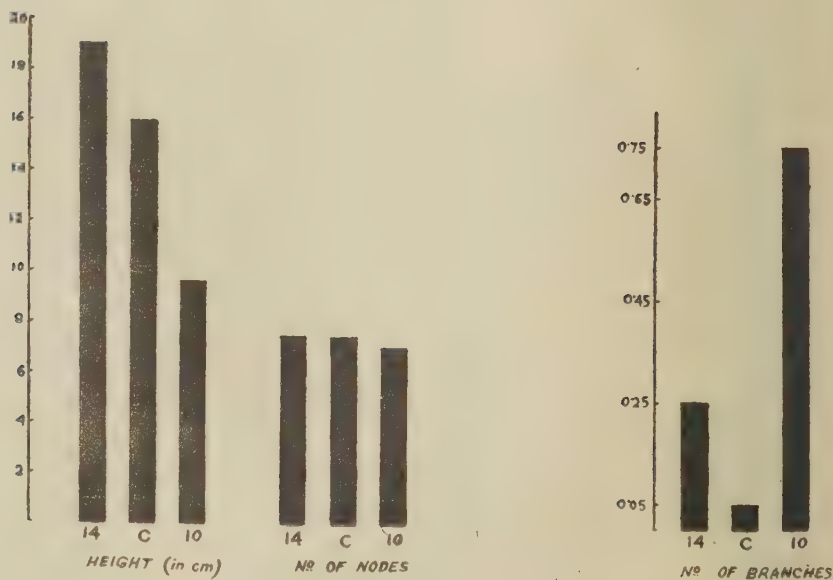
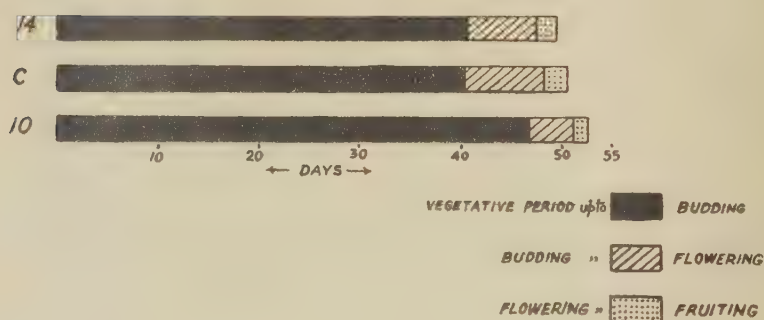


FIG. VA. (I.P.28)

14 - 14 HOURS TREATMENT

G - CONTROL

10 - 10 HOURS TREATMENT

Fig. V A. Graphical representation of the mean data for budding, flowering, and fruiting time, and the total height, number of nodes, leaves and branches.

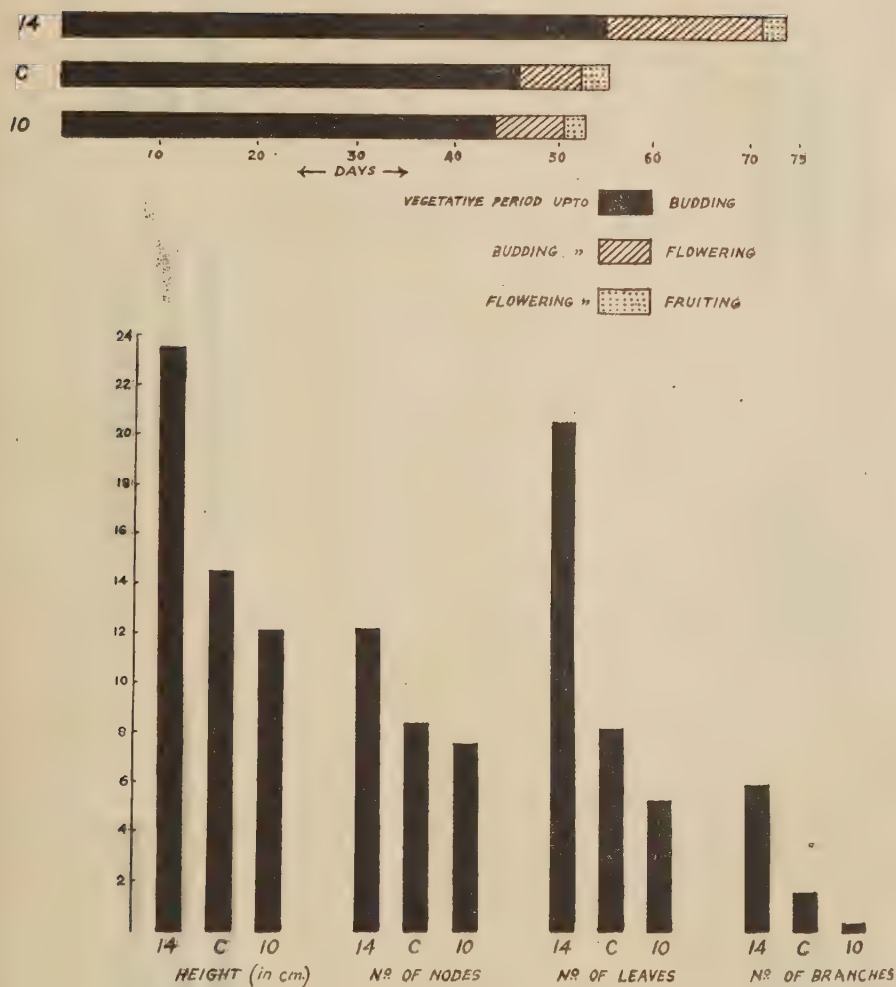


FIG V B
(SONA MUNG)

14 - 14 HOURS TREATMENT
C - CONTROL
10 - 10 HOURS TREATMENT

Fig. V B. Graphical representation of the mean data for budding, flowering and fruiting time, and the total height, number of nodes, leaves and branches.

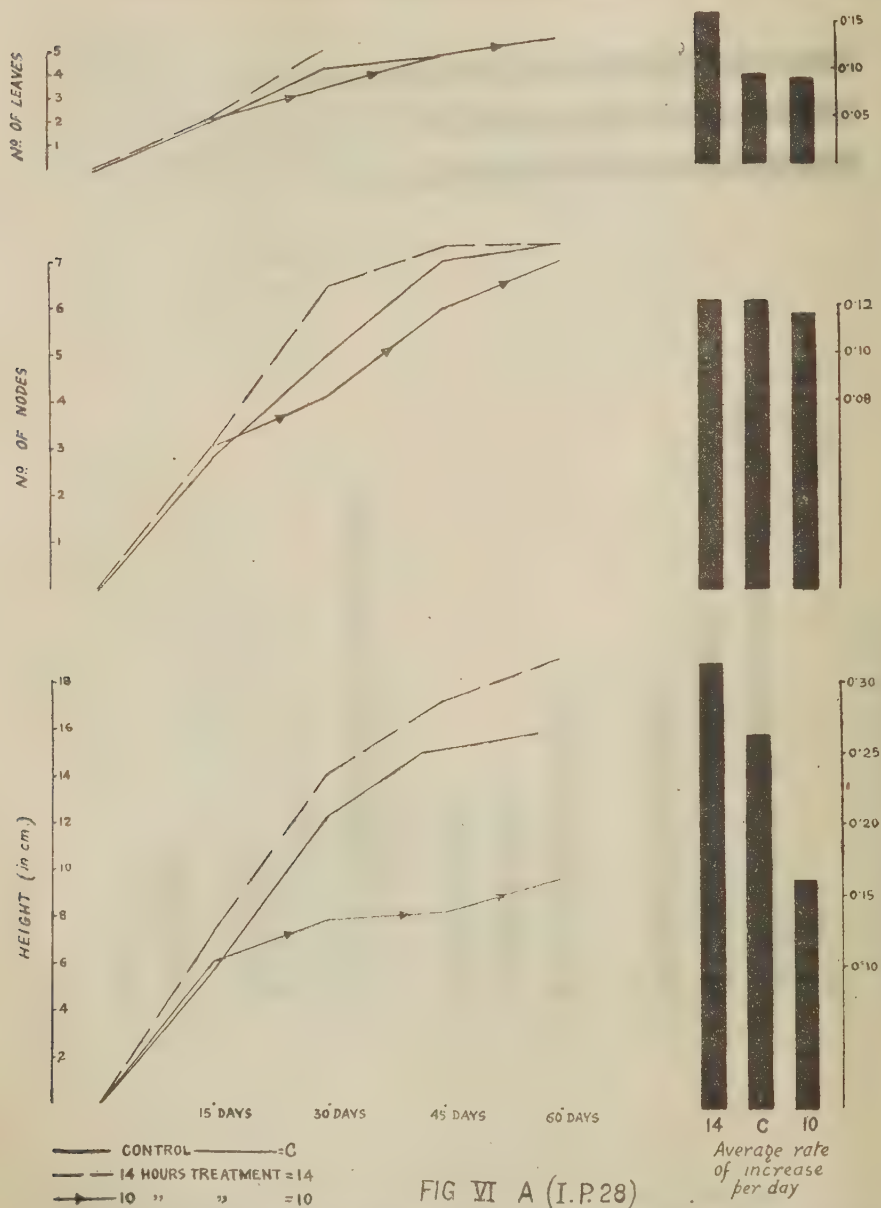


FIG VI A (I.P.28)

FIG. VI A. Graphical representation of heights, the number of nodes, leaves and branches, the increase every 15 days, and average rate of increase per day.

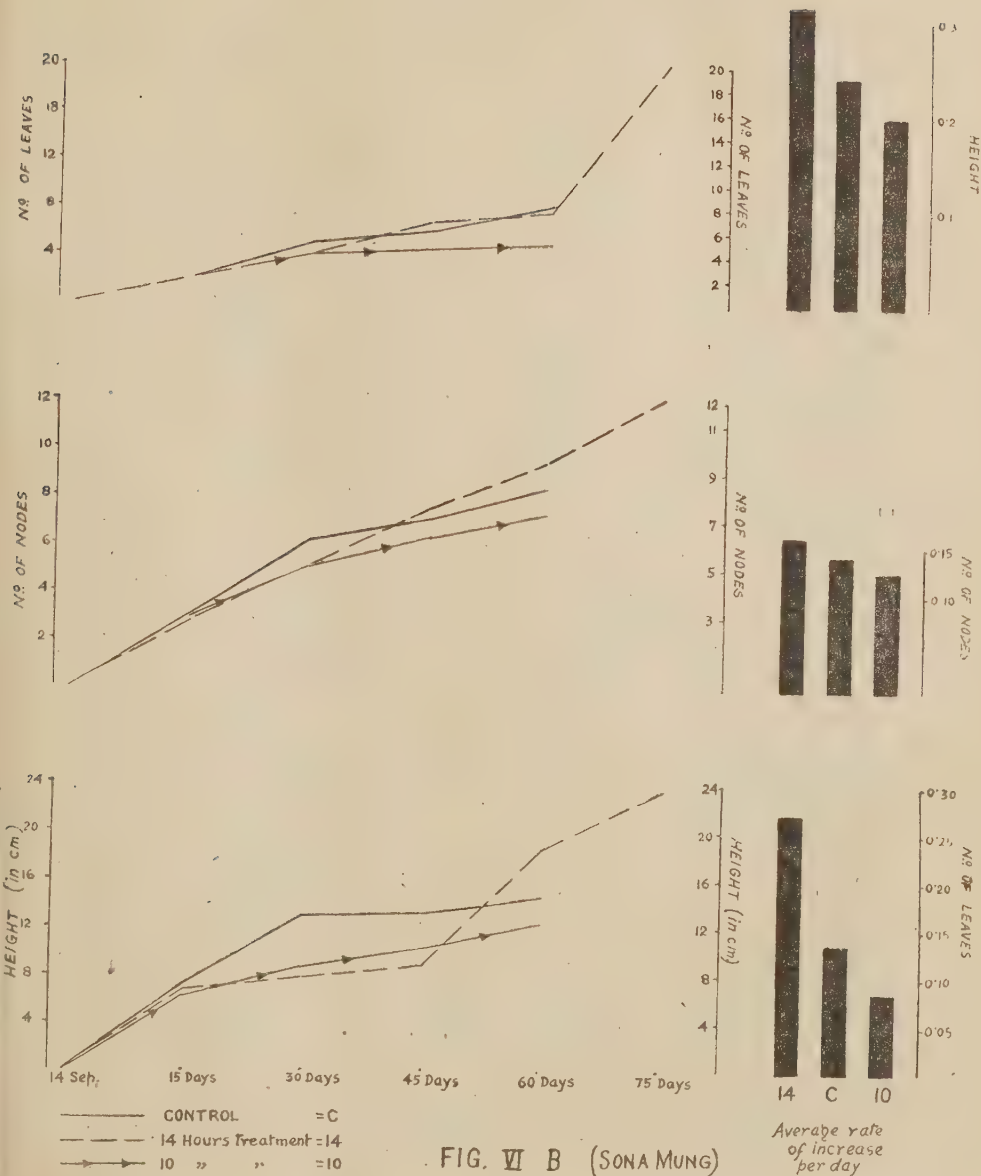


FIG. VI B (SONA MUNG)

Fig. VI B. Graphical representation of heights, the number of nodes, leaves and branches, the increase every 15 days, and average rate of increase per day.

PHOTOPERIODISM

The mean data for budding, flowering, and fruiting time, and the total height number of nodes, leaves and branches formed are tabulated in Tables VI-A and VI-B and graphically represented in Figs. V-A and V-B for I. P. 28, and *Sona Mung* respectively. The heights, the number of nodes, leaves, and branches, the increases every 15 days, and the average rate of increase per day, are given in Tables VII-A and VII-B and graphically represented in Figs. VI-A and VI-B for I. P. 28 and *Sona Mung* respectively.

The light periods to which the plants were treated were 10 hours and 14 hours, the effects of which on the plants are compared with the control which was exposed to normal light period of the days.

TABLE VI-A
(*Mung I. P. 28*)

Treatment	Dates of				Days after sowing				Days between		Totals reached			
	Budding	Flowering	Fruiting		Budding	Flowering	Fruiting		Budding and flowering	Flowering and fruiting	Height	Nodes	Leaves	Branches
14 hours	24 October	1 Novem-ber	1 Novem-ber		40-65	47-55	49-70		6-90	2-15	19-95	7-37	*	0-25
Control	24 October	2 Novem-ber	4 Novem-ber		40-45	48-55	50-72		8-10	2-17	15-87	7-37	*	0-05
10 hours	31 October	4 Novem-ber	6 Novem-ber		46-87	51-25	52-75		4-38	1-50	9-60	7-00	5-40	0-75

Treatment	Dates of			Earliness (+) or lateness (-) to the control			Increase (+) or decrease (-) over the control		
	Budding	Flowering	Fruiting	Budding	Flowering	Fruiting	Height	Nodes	Leaves
14 hours	24 October	1 Novem-ber	3 Novem-ber	-0-20	1-00	+1-02	+3-08	-	-
Control	24 October	2 Novem-ber	4 Novem-ber	-	-	-	-	-	-
10 hours	31 October	4 Novem-ber	6 Novem-ber	-6-42	-2-70	-2-03	-6-27	-0-37	-

*Total number of leaves decreased at the final observation as many of them were shed before fruiting

TABLE VI-B
(*Sona Mung*)

	Dates of			Days after sowing			Days between		Totals reached			
	Budding	Flowering	Fruiting	Budding	Flowering	Fruiting	Budding and flowering	Fruiting and flowering	Height	Nodes	Leaves	Branches
14 hours	8 November	24 November	27 November	55-25	71-33	73-50	16-08	2-17	23-47	12-24	20-47	5-88
Control	30 October	6 November	9 November	46-10	52-84	55-47	6-74	2-63	14-53	8-40	8-20	1-55
10 hours	28 October	4 November	6 November	44-10	51-09	58-10	6-99	2-10	12-15	7-60	5-25	0-35

	Dates of			Earliness (+) or lateness (-) to the control			Increase (+) or decrease (-) over the control				
	Budding	Flowering	Fruiting	Budding	Flowering	Fruiting	Height	Nodes	Leaves	Branches	
14 hours	8 November	24 November	27 November	-9-15	-18-49	-18-03	+8-94	+8-84	+12-27	+4-33	
Control	30 October	6 November	9 November	-	-	-	-	-	-	-	
10 hours	28 October	4 November	6 November	+2-00	+1-75	+2-37	-2-38	-0-80	-2-95	-1-20	

TABLE VII-A

(Mang I. P. 28)

Height

Treatment	Totals reached				Increase (+) or decrease (—) over the control				Increases between			Average rate of increase per day
	Days after sowing				Days after sowing				15th to 30th day	30th to 45th day	45th to 60th day	
	15	30	45	60	15	30	45	60				
14 hours	7.35	14.11	17.20	18.95	+1.52	+1.85	+2.25	+3.08	6.76	3.09	1.75	0.316
Control	5.83	12.26	14.95	15.87	—	—	—	—	6.43	2.69	0.92	0.264
10 hours	6.13	7.85	8.33	9.60	+0.30	—4.41	—0.62	—6.27	1.72	0.48	1.27	0.160
<i>Number of nodes</i>												
14 hours	3.00	6.42	7.30	7.37	+0.20	+1.42	+0.30	—	3.42	0.88	0.07	0.122
Control	2.80	5.00	7.00	7.37	—	—	—	—	2.20	2.00	0.37	0.122
10 hours	3.00	4.18	6.00	7.00	+0.20	—0.82	—1.00	—0.37	1.18	1.82	1.00	0.116
<i>Number of leaves</i>												
14 hours	2.00	4.82	4.80	3.16	+0.15	+0.72	—	—	2.82	—0.02	—1.64	0.160
Control	1.85	4.10	4.45	3.84	—	—	—	—	2.25	0.35	—0.61	0.088
10 hours	2.00	3.25	4.50	5.40	+0.15	—0.85	—	—	1.25	0.25	0.90	0.090
<i>Number of branches</i>												
14 hours	—	—	—	0.25	—	—	—	+0.20	—	—	0.25	—
Control	—	—	—	0.05	—	—	—	—	—	—	0.05	—
10 hours	—	—	—	0.75	—	—	—	+0.70	—	—	0.75	—

TABLE VII-B

(Sona Mung)

Height

Treatment	Totals reached					Increase (+) or decrease (—) over the control					Increases between				Average rate of increase per day
	Days after sowing					Days after sowing									
	15	30	45	60	75	15	30	45	60	15th to 30th day	30th to 45th day	45th to 60th day	60th to 75th day		
14 hours	6.71	7.85	8.75	18.43	23.47	-0.14	-5.08	-4.53	+3.95	1.14	0.90	9.73	14.99	0.316	
Control	6.85	12.93	13.23	14.53	—	—	—	—	—	6.08	0.85	1.25	—	0.242	
10 hours	6.38	8.91	10.25	12.15	—	-0.47	-4.02	-3.03	-2.38	2.53	1.34	1.90	—	0.202	
Number of nodes															
14 hours	2.85	5.00	7.45	9.45	12.24	(-)0.15	(-)1.15	(+)0.35	(+)1.05	2.25	2.85	2.00	2.79	0.163	
Control	3.00	6.25	7.00	8.40	—	—	—	—	—	3.25	0.85	1.30	—	0.140	
10 hours	3.00	5.11	6.70	7.60	—	—	(-)1.14	(-)0.40	(-)0.80	2.11	1.60	0.90	—	0.126	
Number of leaves															
14 hours	1.93	4.25	6.90	7.90	20.47	-0.05	-0.85	+0.75	-0.30	2.30	1.65	1.00	12.57	0.272	
Control	2.00	5.10	6.15	8.20	—	—	—	—	—	3.10	1.05	2.05	—	0.136	
10 hours	2.00	4.12	4.75	5.25	—	—	-0.98	-1.40	-2.95	2.12	0.63	0.50	—	0.087	
Number of branches															
14 hours	—	—	0.30	1.35	5.88	—	—	+0.20	+0.30	—	0.30	1.55	4.03	—	
Control	—	—	0.10	1.55	—	—	—	—	—	—	0.10	1.45	—	—	
10 hours	—	—	0.15	0.85	—	—	—	+0.05	-1.20	—	0.15	0.20	—	—	

VERNALIZATION

Effect of pre-sowing low temperature treatment (2°C.—4°C.) for 10 days

The mean data for the time of budding, flowering, and fruiting, the total height reached, number of nodes, leaves, and branches formed, are given in the Tables VIII-A and VIII-B and represented graphically in Figs. VII-A and VII-B for I. P. 28 and *Sona Mung* respectively. The heights, number of nodes, leaves, and branches, the increase every 15 days, and the average rate of increase per day are tabulated in Tables IX-A and IX-B and graphically represented in Figs. VIII-A and VIII-B for I. P. 28 and *Sona Mung* respectively.

TABLE VIII-A
(*Mung I. P. 28*)

Treatment	Dates of			Days after sowing			Days between		Totals reached			
	Budding	Flowering	Fructing	Budding	Flowering	Fructing	Budding and flowering	Flowering and fructing	Height	Nodes	Leaves	Branches
10 days Control	27 October	2 November	4 November	43.15	43.84	50.68	5.69	1.84	15.60	7.66	3.53*	0.13
	24 October	2 November	4 November	40.45	49.55	50.72	8.10	2.17	15.87	7.37	3.84*	0.05

Treatment	Dates of			Days after sowing			Days between		Totals reached			
	Budding	Flowering	Fructing	Budding	Flowering	Fructing	Budding and flowering	Flowering and fructing	Height	Nodes	Leaves	Branches
10 days Control	27 October	2 November	4 November	—2.70	—0.29	+0.04	+0.04	—	+0.73	+0.29	—	+0.08
	24 October	2 November	4 November	—	—	—	—	—	—	—	—	—

* Due to shedding of leaves

Increase (+) or decrease (—) over the control

TABLE VIII-B
(*Sona Mung*)

Treatment	Dates of			Days after sowing			Days between		Totals reached			
	Budding	Flowering	Fructing	Budding	Flowering	Fructing	Budding and flowering	Flowering and fructing	Height	Nodes	Leaves	Branches
10 days Control	1 November	4 November	6 November	48.84	51.38	53.35	2.54	1.97	11.85	8.60	7.85	1.45
	30 October	6 November	9 November	46.10	52.84	55.47	6.74	2.63	14.53	8.40	8.20	1.55
10 days Control	2 October	4 November	6 November	—2.74	+1.46	+2.12	+2.12	—	—2.68	—0.20	—0.35	—0.10
	30 October	6 November	9 November	—	—	—	—	—	—	—	—	—

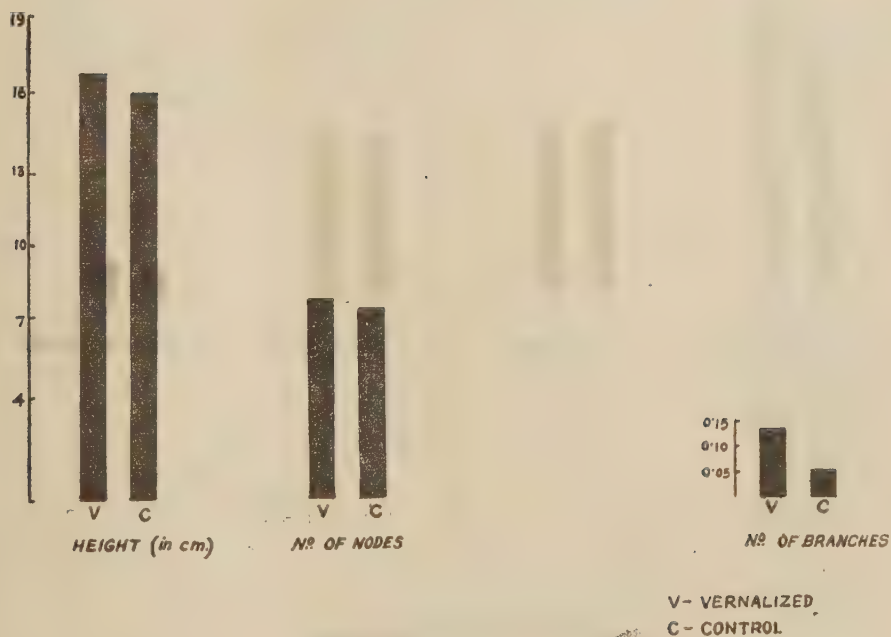
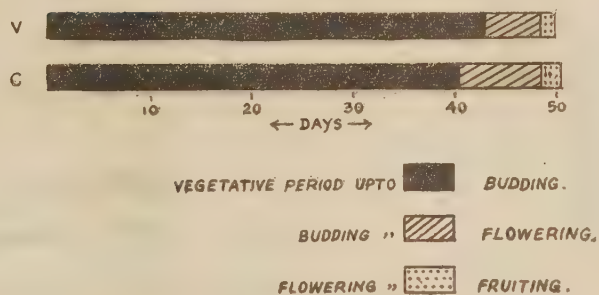


FIG VII A. (I.P.28)

FIG. VII A. Graphical representation of mean data for the time of budding, flowering and fruiting, the total height, number of nodes, leaves and branches

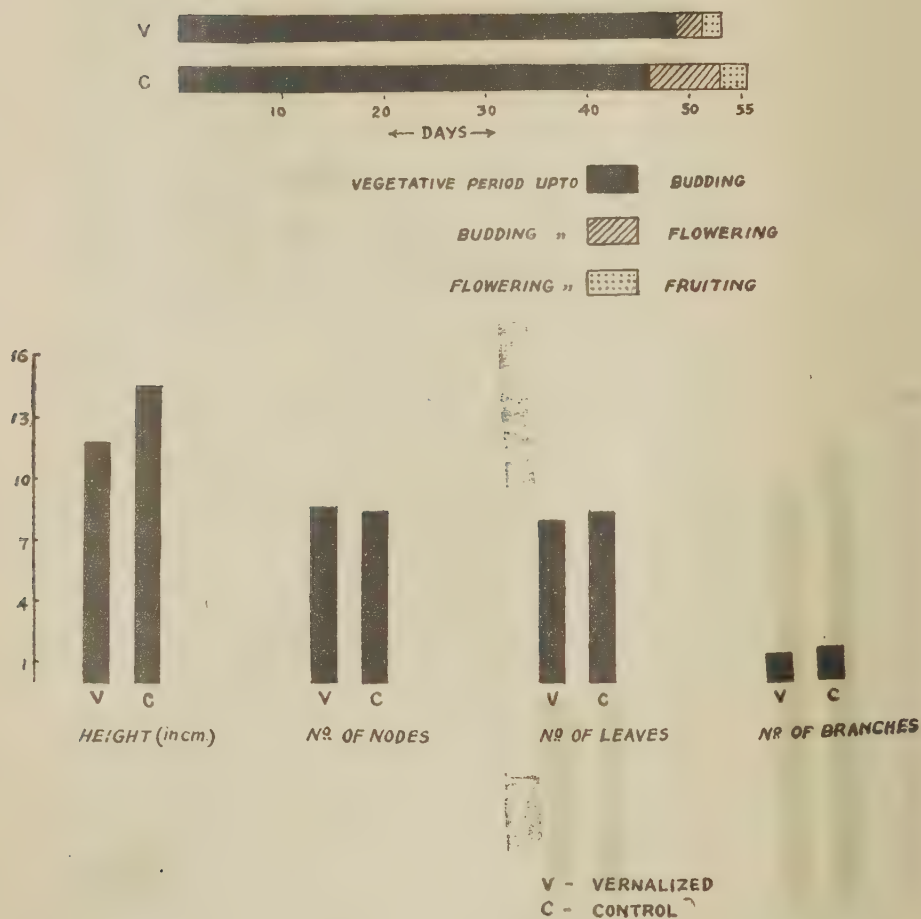


FIG VII B (SONA MUNG)

FIG. VII B. Graphical representation of mean data for the time of budding, flowering and fruiting, the total height, the number of nodes, leaves and branches

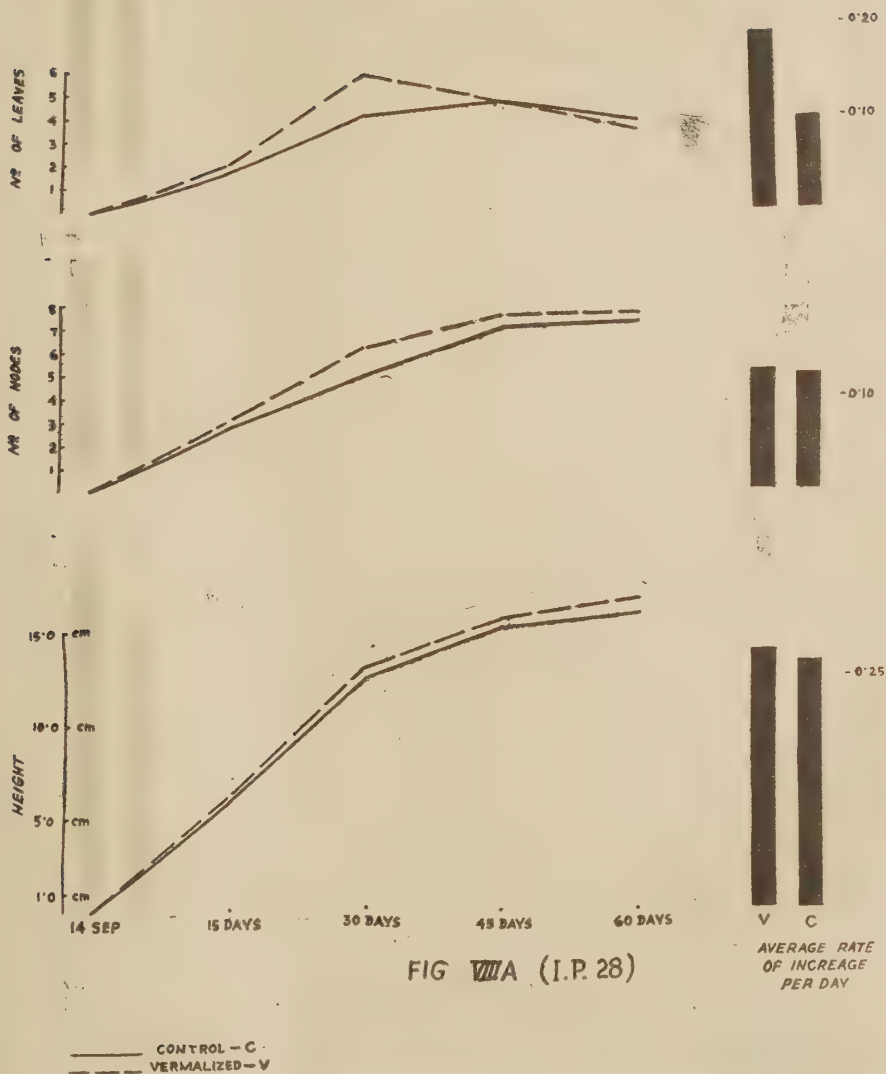


FIG. VIII A. Graphical representation of heights, number of nodes, leaves and branches, the increase every 15 days, and average rate of increase per day

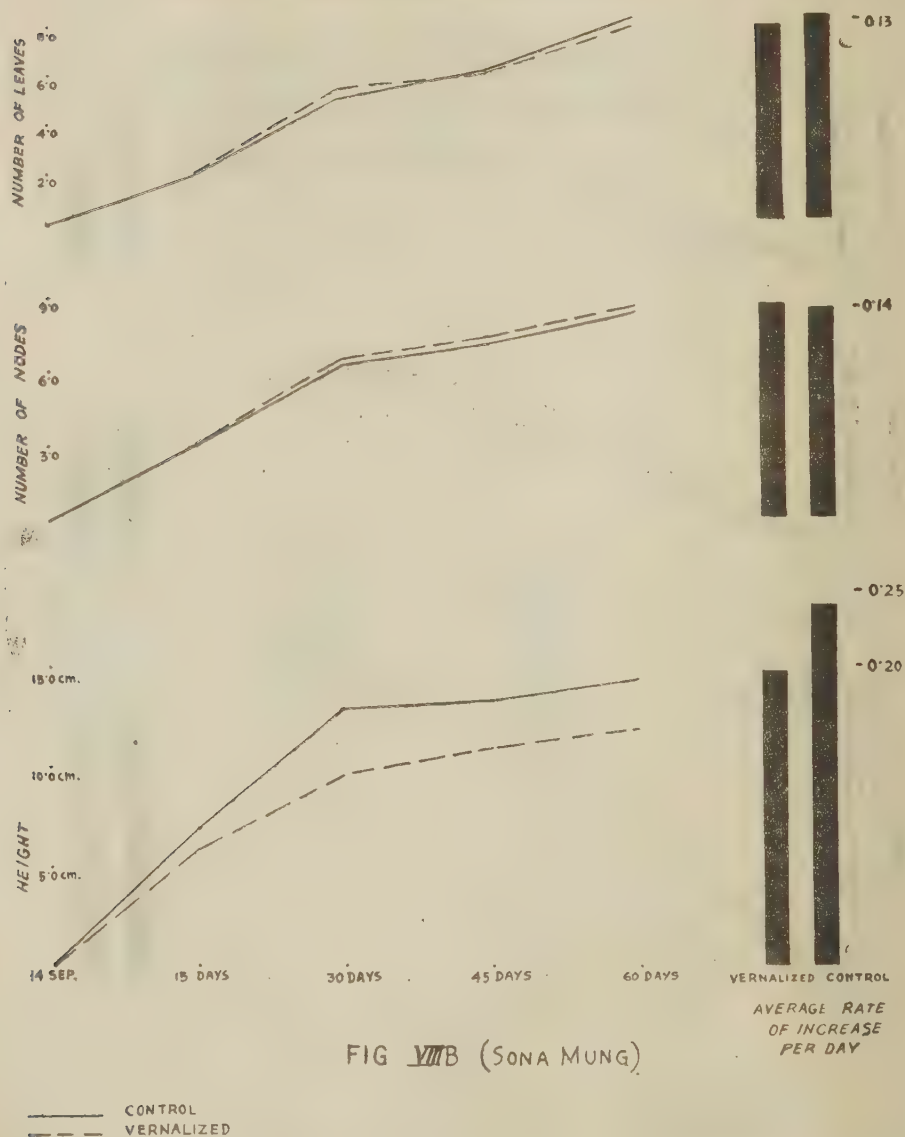


FIG. VIII B. Graphical representation of heights, number of nodes, leaves and branches, the increase every 15 days, and average rate of increase per day

TABLE IX-A
(Mung I. P. 28)

Height

Treatment	Totals reached Days after sowing					Increase (+) or decrease (—) over Days after sowing					Increases between				Average rate of increase per day
	15	30	45	60		15	30	45	60		15th to 30th days	30th to 45th days	45th to 60th days		
10 days	6.03	12.99	15.43	16.60		+0.20	+0.73	+0.48	+0.73		6.96	2.44	1.17*		0.276
Control	5.83	12.26	14.95	15.87		—	—	—	—		6.43	2.69	0.92		0.264
<i>Number of nodes</i>															
10 days	3.05	6.10	7.40	7.66		+0.25	+1.10	+0.40	+0.28		3.05	1.30	0.26		0.127
Control	2.80	5.00	7.00	7.37		—	—	—	—		2.20	2.00	0.37		0.122
<i>Number of leaves</i>															
10 days	2.05	5.73	4.40	3.53		+0.20	+1.63	—	—		3.68	—1.33*	—0.87*		0.191
Control	1.85	4.10	4.45	3.84		—	—	—	—		2.25	0.34	—0.31*		0.098
<i>Number of branches</i>															
10 days	—	—	—	0.13		—	—	—	+0.08		—	—	0.13		—
Control	—	—	—	0.05		—	—	—	—		—	—	0.05		—

*Due to shedding of leaves

TABLE IX-B

(Sona Mung)

Height

Treatment	Totals reached Days after sowing				Increase (+) or decrease (—) than the control Days after sowing				Increase between			Average rate of increase per day
	15	30	45	60	15	30	45	60	15th to 30th day	30th to 45th day	45th to 60th day	
	5-92 6-85	9-61 12-93	10-80 13-23	11-85 14-53	-0-93 —	-3-32 —	-2-48 —	-2-63 —	3-69 6-08	1-19 0-35	1-05 1-25	0-197 0-242

Number of nodes

10 days	3-00	6-50	7-40	8-60	—	+0-25	+0-30	+0-20	3-50	0-90	1-20	0-143
Control	3-00	6-25	7-10	8-40	—	—	—	—	3-25	0-85	1-30	0-140

Number of leaves

10 days	2-00	5-45	6-10	7-85	—	+0-35	-0-05	-0-35	3-45	0-65	1-75	0-130
Control	2-00	5-10	6-15	8-20	—	—	—	—	3-10	1-05	2-05	0-136

Number of branches

10 days	—	[0-10	0-65	1-45	—	+0-10	+0-55	-0-10	0-10	0-55	0-80	—
Control	—	—	0-10	1-55	—	—	—	—	—	0-10	1-45	—

METEOROLOGICAL DATA

The mean values for every 15 days of the different meteorological factors, viz., the maximum and minimum temperatures, rainfall, relative humidity, daylength, and the total hours of bright sunshine are tabulated in Table X, and graphically represented in Fig. IX.

TABLE X

Meteorological data

Dates	Maximum tempera- ture	Minimum Tempera- ture	Rainfall	Relative humidity	Length of day Hrs. Min.	Total hours of bright sunshine
1 December 1944	83.5	58.4	0.00	61.6	10—35	8.9
15 December 1944.						
1 January 1945	82.1	57.8	0.00	58.2	10—35	8.9
15 January 1945	75.2	53.7	0.06	62.4	10—47	9.2
1 February 1945	79.9	54.4	0.00	51.1	10—56	9.1
15 February 1945	84.2	58.8	0.02	51.3	11—12	9.2
1 March 1945	85.2	59.0	0.00	48.8	11—32	9.5
15 March 1945	92.6	67.0	0.30	44.2	11—48	9.4
1 April 1945	96.7	75.3	0.00	56.4	12—14	9.9
15 April 1945	95.6	77.4	0.03	59.7	12—32	9.0
1 May 1945	92.2	72.0	0.23	62.8	12—51	8.9
15 May 1945	96.8	79.0	0.14	67.9	13—00	9.7
1 June 1945	95.0	77.5	0.14	70.8	13—18	7.9
15 June 1945	95.8	82.0	0.02	71.9	13—15	6.4
1 July 1945	93.8	79.2	0.51	84.5	13—15	3.5
15 July 1945	89.8	79.9	0.29	82.5	13—09	5.2
1 August 1945	92.0	80.3	0.19	78.3	12—57	4.9
15 August 1945	92.4	80.5	0.17	78.3	12—53	4.3
1 September 1945	89.4	79.3	0.28	88.0	12—34	5.3
15 September 1945	90.1	79.9	0.13	81.4	12—15	4.3
1 October 1945	90.8	78.5	0.59	85.0	11—53	4.5
15 October 1945	90.6	76.9	0.13	76.6	11—34	6.7
1 November 1945	89.1	72.0	0.59	85.5	11—26	6.0
15 November 1945	86.6	68.0	..	64.8	10—56	9.2
1 December 1945	83.1	60.2	0.00	59.6	10—42	9.7
15 December 1945	80.2	57.0	0.00	58.1	10—36	9.3
31 December 1945	77.06	52.7	0.00	60.1	10—35	9.3

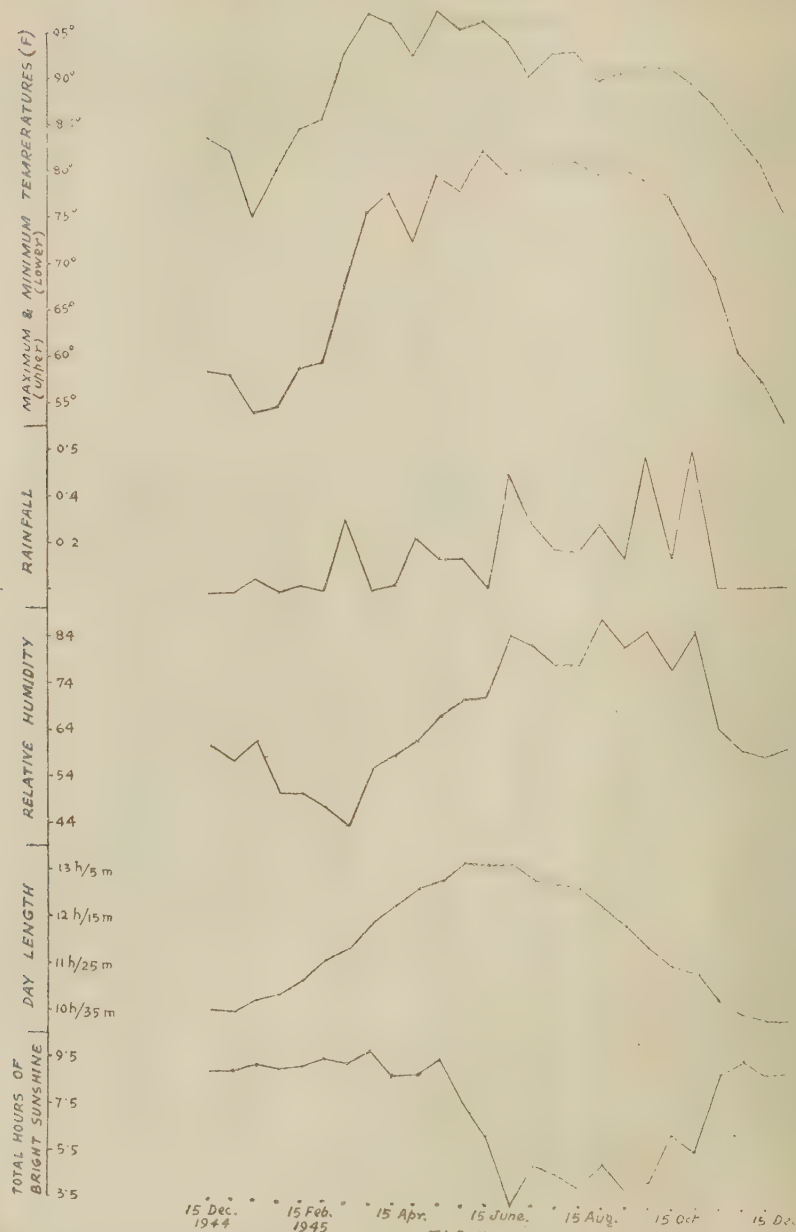


FIG IX. Graphical representation of mean values for every 15 days of the different meteorological factors.

DISCUSSION

Growth and development of a plant depend upon several environmental factors which act simultaneously. It is impossible to interpret the behaviour of a plant with regard to a particular environmental factor if all the factors were not kept under strict control. When the plants are sown at different times of the year, they are exposed to the natural variation of the environmental factors in which practically all the factors vary simultaneously and the plants of subsequent sowings are exposed to the same environmental factors at different ages. A clear correlation of the variation in growth and development of the plants to the different meteorological factors is, thus, not possible. An attempt may, however, be made to find out the dominant factor or factors for the promotion of vegetative and reproductive growth.

In both the varieties, the vegetative growth of the plants decreased as the sowing was delayed from 15 August to 29 October 1945. During this period (extending upto 15 December 1945) the daily light period gradually decreased from 12 hrs. 53 minutes to 10 hrs. 36 minutes, the maximum and the minimum temperature from 92.4° and 80.5° F. to 80.2° and 57.0° F. respectively, the rainfall remained high till the 1 November after which dry period set in without any rainfall and the humidity gradually fell to 58.1. The period of bright sunshine rose from 4.3 to 9.7 hrs. from 15 August to 1 December 1945. The growth in height fell to comparatively low values in the last two sowings—the 14 and the 29 October, 1945. In *Sona Mung* the fall in height from the 15 August to the 30 August sowing was very great. A slight increase was noticed in the total height in the 14 September sowing of *Sona Mung*.

Amongst the sowings from 16 October 1944 to 25 March 1945, of I. P. 28, the lowest growth in height was recorded for the 24 January sowing, the next higher was the 26 October sowing, the next higher was the 25 December sowing, the next higher was the 25 November sowing and in 23 February and 25 March sowings the heights were comparatively much higher than the other sowings. The daily light period decreased gradually from 11 hrs. 15 minutes to 10 hrs. 35 minutes between the 1 November 1944 to 1 January 1945 after which it gradually rose upto 13.00 hours on the 15 May. The maximum and minimum temperature gradually decreased from 83.5° F. and 58.4° F. to 75.2° F. and 53.7° F. from 15 December, 1944 to 15 January 1945 and from 15 January gradually rose to 96.7° F. and 75.3° F. on 1 April and were 96.8° F. and 79.0° F. respectively on 15 May with an intermediate value on the 1 May. Rainfall was *nil* after 15 November 1944 and the humidity gradually decreased and became only 44.2 on the 15th March 1945. The period of bright sunshine reached the highest value (9.9) on the 1st April 1945.

It was noticed that the vegetative growth was particularly retarded in the October sowing. This may be due to the shortening of the daylight, lowering of the temperature and humidity. Eaton [1924] suggested that temperature influenced growth and flower production of soyabean as did the daylength. Tincker [1928] observed by sowing *Phaseolus multiflorus* at different dates, that 'the temperature effect in June, July and August could hardly be such as to limit growth. In Sep-

tember and October temperature was undoubtedly a most important factor'. He found that with the lateness of sowing from May 9 to September 9, the plants became shorter, and the sowings at the end of August and September produced no fruits and ultimately became checked in growth. Tincker explains the latter condition as an effect of low temperature. In present investigation it was also found that in the December, January and March Sowings several plants died before reproduction. The percentages of the plants died before budding are 35 per cent, 45 per cent and 35 per cent, before the opening of flower are 45 per cent, 55 per cent and 55 per cent and before the fruiting age are 55 per cent, 65 per cent and 60 per cent in the 25 December, 24 January and 25 March sowings respectively of I. P. 28. These may be accounted for as due to very low minimum temperature in the first two and very high maximum temperature in the last sowing. The temperature, perhaps, also regulates the opening of the flower. Another external factor, which is not the least important, comes into prominence in this case. This factor is the entire absence of the rainfall. The 25 November and 25 December sowings are characterised by having the longer vegetative periods and they took 18 days from the initiation of flower buds to the opening of flowers. This retardation of the reproductive growth may be attributed to the low temperature and humidity, and the absence of rainfall.

The influence of rainfall is marked in the 15 August sowing of *Sona Mung* during the later days of the month of September (15 September to 1 October) the rainfall suddenly rose from 0.13 to 0.59. The vegetative growth was markedly enhanced in the 15 August sowing of *Sona Mung* during this period—the increase in the height (11.95), number of nodes (5.70), leaves (11.45) and branches (2.50) being the highest not merely amongst all the stages of the same sowing, but also among all the stages of all the sowings.

Mukherjee [1945] in an experiment on the effect of water supply to *Mung* (I. P. 28) plants, found that the growth increased and the flowering time hastened with an increase in water supply.

It may be said that the daily light period and temperature decreased with the lateness in sowing from 15 August to 29 October and the sum total effects were that the vegetative growth had clearly decreased with the lateness of sowing time during this period in both the varieties of the plant. But the flowering time seems to be influenced in the opposite manner in the two varieties. Experiments of photoperiodic treatment have shown that the flowering time was enhanced in *Sona Mung* and retarded in I. P. 28 with the increase in the length of the light period.

As the sowing time was delayed from 15 August to 29 October the vegetative period of I. P. 28 was lengthened from 34.8 to 49.4 days and that of *Sona Mung* was shortened from 65.5 to 27.0 days. The bud initiation was also delayed as the sowing of I. P. 28 was delayed from 26 October 1944 to 25 December 1944 after which it was enhanced from 60 to 51 days in the 25 March sowing. This may be co-related with the length of day and the temperature, both of which gradually decreased from August to January and increased from January onwards. The

rainfall was also of influence in this connection, as it was found in 1945 that an increase in the water supply induced earliness in the initiation of the reproductive phase in I. P. 28. It is, however, not possible to say which of the three factors was or were more dominating in this case without further researches in this line. All the more difficult is the question of correlating the cases of exception to the general trend in the case of the 14 September sowing in I. P. 28, in relation to its budding and fruiting period, the fruiting time of the 15 August sowing, and the flowering time of the 14 October sowing, to definite factor or factors; although it should be remembered that the differences in question are very slight in most of these cases, and that the data presented are the mean of readings of 20 plants in each case.

If the relative effects of 10-hour and 14-hour light treatments on the initiation of the reproductive phase in the two varieties are compared, it becomes clear that the shorter light period enhanced the flowering time and longer light period retarded it in I. P. 28, whereas in *Sona Mung* the longer light period enhanced the flowering time and shorter light period retarded it. The nature of the response to the different light periods is therefore reverse in the two varieties.

Tincker [1928] observed that 'seasonal length of day regulated the elongation of the stem in a similar manner to the artificially controlled day-light'. He found that 'short day' caused *Phaseolus multiflorus* to remain as branched dwarfs and to flower earlier. The result tallies with the present investigation as regards dwarfness is concerned, but flowering time of one variety of *Mung* was reverse of the other, *Sona Mung* flowering earlier with short photoperiod and was associated with the least number of branches as opposed to Tincker's observations, and I. P. 28 behaves just in the reverse manner.

The photoperiodic response, as recorded by the differences in the flowering time in relation to the differences in the light period, is more intense in *Sona Mung* than in I. P. 28. Further investigations with longer and shorter photoperiodic treatments are necessary for a clear understanding of the further details of the photoperiodic effects.

The photoperiodic results clearly show that the two varieties are entirely different as regards their optimum light requirement and *Sona Mung* requiring a lesser amount of daylight for early initiation of reproductive stage may be called a 'short day plant', whereas the I. P. variety—requiring a greater amount of daily illumination—a 'long day plant' in the same sense of the terms as applied originally by Garner and Allard [1920].

Similar fundamental differences in the photoperiodic response have also been recorded by Murneek [1936], viz., the 'Biloxi' variety of soyabean—a short day crop—is considerably retarded in its development by the increase of daylength, whereas the 'Mandarin' variety of the same crop shows little response to such a change and bloom simultaneously. Oakley and Westover [1921] distinguished

different varieties of Lucerne by treating them with the illumination for varying periods, and studying their respective responses.

Garner, Bacon and Allard [1924] found an increase in the length of the stem in the 'short day' plants and a decrease in the 'long day' ones when treated with long daily illumination. According to them, an increase in the active acidity of the plants, particularly in the growing point, is associated with the former, and a low level in the acidity with the latter case. Adams [1923] working on flax, wheat, sunflower and a few other plants interpreted that the plants exposed longest to the action of light attained the greatest height and flowered earlier. Tincker [1928] did not observe increased elongation in *Phaseolus multiflorus* treated with short day light. Redington [1929] found that *Pisum*, *Vicia*, etc., grew best in longer exposure to illumination.

The authors did not find increased elongation of the stem due to short photoperiod in any of the two varieties of *Mung*. This result partly tallies with that of Garner, Bacon and Allard, and fully with that of Tincker and Adams in that the height was the greatest in the plants treated with longer daily illumination.

In the treatments which prolonged the vegetative period, the ultimate height, number of nodes, leaves and branches were also much greater. This behaviour which was also found by Murneek was explained by him by stating that when blooming was retarded the organic substances elaborated were directed towards the formation of new leaves. Long day plants grown in shorter daylength would have greater vegetative growth, but due to reduction in the photosynthesis period there would be lesser accumulation of organic substances, which might be the cause for the lesser growth in the case of I. P. 28.

The pre-sowing low-temperature treatments of 10 days reported here seem to have no clear responses, though some earliness or lateness in the stages of budding, flowering and fruiting and some differences in the vegetative growth have been recorded. The response, though feeble, seems to be more evident in *Sona Mung*. It will however be useful to try longer periods of vernalization treatments, but an experiment on 45-day treatment has shown that these seeds failed to germinate.

Lastly, it is an important observation that the dates of the initiation of the reproductive phase for the six successive sowings of *Sona Mung* lie between 20 October and 25 November and in general, in the month of November—which can well be said to have the optimum external conditions for the reproductive phase of *Sona Mung*. In I. P. 28 this is not at all noticeable, the initiation of the reproductive phase taking place on widely separated days between 19 September and 17 December for the same set of sowings. The behaviour of *Sona Mung* in this respect can be said to be similar to the jute plants, ('short day' plants) where for widely separated dates of sowing (1 April to 30 June) the flowering takes place within the narrow period between the middle of August and the middle of September (in press.)

SUMMARY

For each treatment five pots with four plants each were used.

Two varieties of *Mung* (*Phaseolus aureus* Roxb.)—I. P. 28 and *Sona Mung*—were sown at intervals of 15 days from 15 August 1945 to 29 October 1945; there being six sowings. For I. P. 28 there were six sowings in addition at intervals of 30 days from 26 October 1944 to 25 March 1945.

Sown on 14 September 1945 the plants of both the varieties were subjected to 10-hour and 14-hour daily light treatment.

Sown on the same date one set of seeds was subjected to pre-sowing cold temperature treatment (2°C.—4°C.) for 10 days.

For sowings between 15 August to 29 October, the flowering time was reduced with the lateness of sowing in *Sona Mung*, but in I. P. 28 the flowering time was enhanced with the lateness of sowing.

For the same period the vegetative growth in both the variety decreased with the lateness of sowing.

For the sowing of I. P. 28 between 26 October 1944 to 25 March 1945, the flowering time tended to increase till the December sowing after which it tended to decrease till the March sowing. The vegetative growth however did not show any regularity in its trend of variation.

The relative influence of meteorological factors on growth and development of the plants has been discussed.

The I. P. 28, variety behaved as a 'long day' plant and *Sona Mung* as a 'short day' plant, the nature of photoperiodic response is therefore reverse in the two varieties.

The response to pre-sowing low-temperature treatment (vernalization) of 10 days was not distinct and clear.

ACKNOWLEDGEMENT

Our thanks are due to the Directors of the Indian Agricultural Research Institute, New Delhi and the Department of Agriculture, Government of Bengal, for the supply of seeds of the I. P. 28 variety of *Mung* and *Sona Mung* respectively. Our thanks are also due to the Director, the Meteorological Observatory, Alipore for the Meteorological data.

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EXPLANATION OF PLATES

PLATE II

FIG. 1. Sown on 15 August, 1945.

Photograph taken on 14 October 1945.

Age of the plants—60 days.

Experiment—Time of Sowing.

Showing that at the time when *Sona Mung* (3) was about to flower, the I. P. 28 (3A) variety was at the end of its life.

(*Sona Mung* produced flower buds in 65·50 days and Mung I. P. 28 in 34·80 days).

FIG. 2. Sown on 29 September, 1945.

Photograph taken on 29 October, 1945.

Age of the plants—30 days.

Experiment—Time of Sowing.

Showing that *Sona Mung* (103) and I. P. 28 (56) variety were almost similar in their growth and development, though greater number of leaves can be noticed in *Sona Mung*

(*Sona Mung* produce flower buds in 34·85 days and Mung I. P. 28 in 39·70 days).



FIG. 1.



FIG. 2.

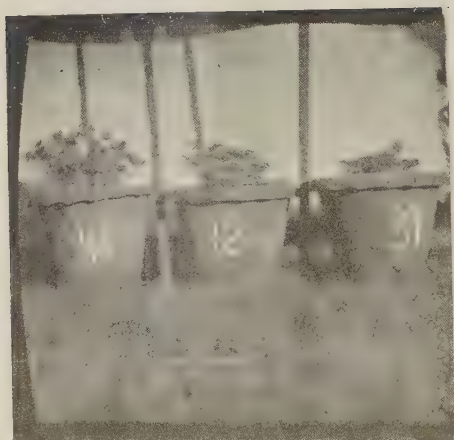


FIG. 3.



FIG. 4.



FIG. 5.

PLATE III

FIG. 3. Sown on 14 September, 1945.

Photograph taken on 29 October, 1945.

Age of the plants—45 days.

Experiment—Photoperiodism.

Showing that the vegetative growth in *Sona Mung* was the highest in the 14-hour illuminated plants (46), next higher in the controls (12) and the lowest in the 10-hour illuminated plants (39).

(The 14-hour treated plants produced flower buds in 55.25 days, the controls in 46.10 days, and the 10-hour treated plants in 44.10 days).

FIG. 4. Sown on 14 September, 1945.

Photograph taken on 29 October, 1945.

Age of the plants—45 days.

Experiment—Photoperiodism

Showing that the vegetative growth in *I. P. 28* was the highest in the 14-hour illuminated plants (52), next higher in the controls (20) and the lowest in the 10-hour illuminated plants (41).

(The 14-hour treated plants produced flower buds in 40.65 days, the controls in 40.45 days and the 10-hour treated plants in 46.87 days).

FIG. 5. Sown on 14 September, 1945.

Photograph taken on 6 November, 1945.

Age of the plants—53 days.

Experiment—Photoperiodism Vernalization.

Showing that the vegetative growth in *I. P. 28* was the highest in the 14-hour illuminated plants (51) next higher in the 10-day vernalized one (31), next higher in the controls (16) and the lowest in the 10-hour illuminated plants (45).

(The plants of the Pot. No. 31 seem to be of the same height as those of the Pot No. 51. But this is due to the level of the pots being not even).

PLATE IV

FIG. 6. Sown on 14 September, 1945.

Photograph taken on 21 November, 1945.

Age of the plants—68 days.

Experiment—Photoperiodism and Vernalization.

Showing that the vegetative growth in *Sona Mung* was the highest in the 14-hour illuminated plants (48), next higher in the controls (13), the lowest being the 10-hour illuminated plants (36) and the 10-day vernalized ones (26). The two latter are seen to be at the last stage of their life. Plants of Pot No. 48 are seen to be very strong (These plants produced fruits after 73·50 days, whereas the others produced fruits after 53·10 to 55·47 days).

FIG. 7. Sown on 14 September, 1945.

Photograph taken on 7 December, 1945.

Age of the plants—84 days.

Experiment—Photoperiodism and Vernalization.

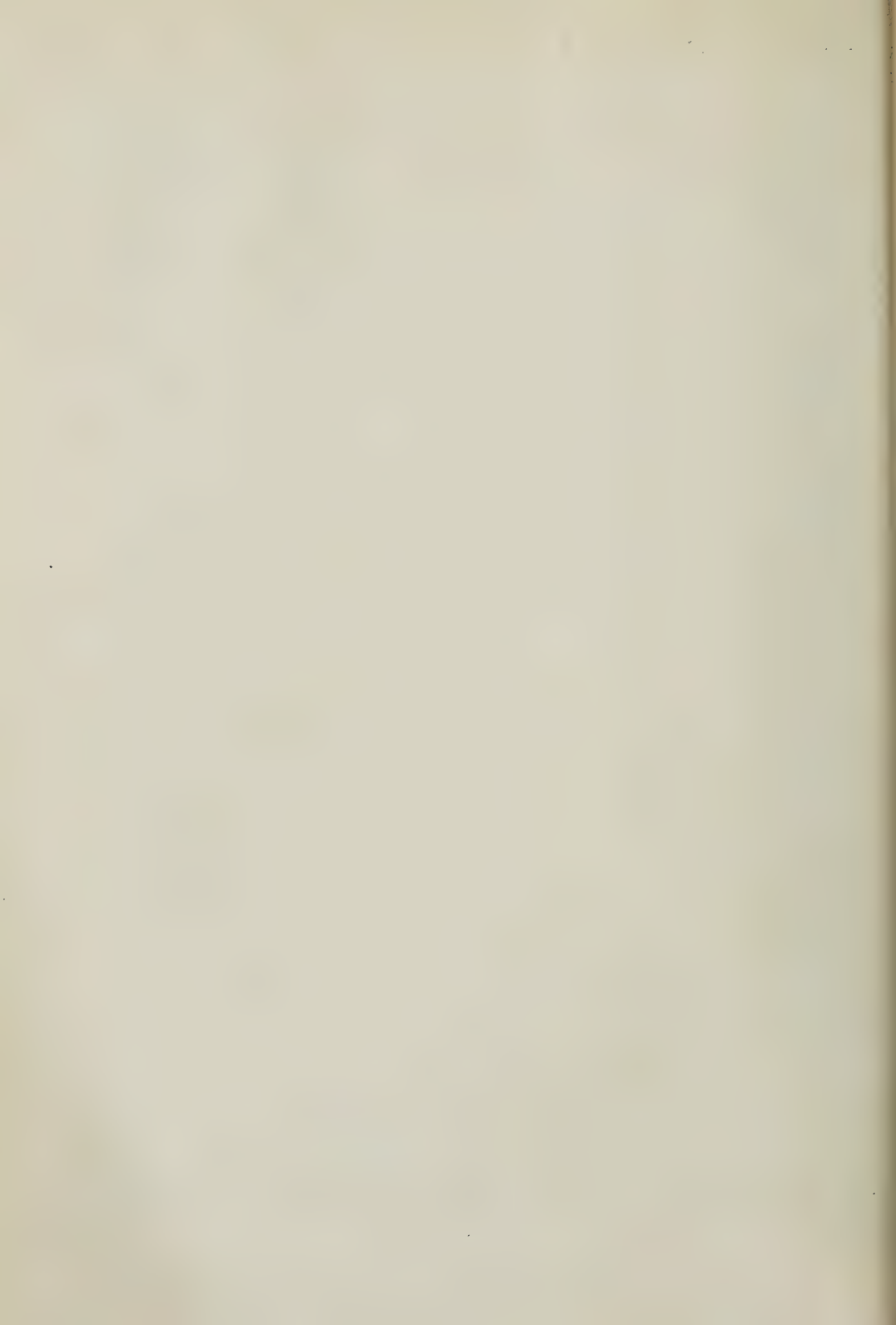
Showing that *Sona Mung* illuminated 14 hours daily (47) was healthy and strong, and produced fruits when the controls (12), the 10-hour illuminated plants (38), and the 10-day vernalized ones (27) all have died.



FIG. 6.



FIG. 7.



STUDIES IN NITROGEN AND CARBOHYDRATE METABOLISM OF SUGARCANE

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THESE studies were started in 1943 with the main object of elucidating the metabolic changes going on in sugarcane under various conditions of growth. The results of an investigation on the growth of the sugarcane as affected by seasonal variations at Shahjahanpur have already been published by Mathur [1941]. A study of the metabolic changes in the cane plant with respect to nitrogen and sugars has not, however, so far been attempted by research workers in India; and to fill up this important gap in the knowledge, the present investigation was undertaken.

A brief review of the literature on the more important work on nitrogen and carbohydrate metabolism is given below.

Sapoznikow [1895] found that there was increase of proteins with increase of carbohydrates in leaf. Chibnall [1922] working on runner beans found that nitrate and mono-amino nitrogen vary directly with protein, indicating that they may be connected with protein synthesis. Phillis and Mason [1947] have shown that proteins in leaf increase as crystalloid nitrogen increases upto a point, and that subsequently an increase of crystalloid nitrogen is accompanied by a decrease in protein nitrogen. Sure and Tottingham [1911] working on peas showed that amino acids are more in evidence during early stages and disappear later. Richard and Templeman [1936] showed that leaves are high in nitrogen when young, but total nitrogen goes down with the age of the leaf because nitrogen travels to the younger parts. Ruhland and Wolf [1936] working on sugarcane leaf found that in the earliest leaves sugars tend to diminish with advancing age of the leaves; but that in the later leaves an opposite effect is perceived. Das [1936] also working on sugarcane found that under conditions of rapid vegetative growth sucrose content is low and reducing sugars are high. In sugarcane the accumulation of sucrose is a node to node process and stops when the leaf attached to the node falls off.

The present study embodies the following aspects :

1. The effect of age on the metabolism of sugarcane.
2. The effect of yellowing disease on sugarcane metabolism.
3. Preliminary observation on the effect of pyrilla infestation on the metabolic processes.

ANALYTICAL METHODS

Prior to the commencement of these investigations modern methods of micro-chemical analysis were adapted to suit the specific requirements.

Total nitrogen was determined by the usual Micro-Kjeldahl method (1).

Crystalloid nitrogen was determined by precipitating proteins from the water extract of the material with trichloro-acetic acid : 5 c.c. of the filtrate was treated with

1 c.c. of 50 per cent sulphuric acid and a pinch of reduced iron. Nitrogen content of this portion was determined by Micro-Kjeldahl method.

Protein nitrogen was expressed as the difference between the total and crystalloid N.

Amino nitrogen was determined by Brown's (2) modification of Sorensen's formal titration method using Phenol red as indicator.

Amide nitrogen was determined by B. Wolf's method (3) of aerating ammonia-free air through N/100 boric acid solution.

Sugars (total, sucrose and reducing) were determined by C. S. Hanes' modification (4) of Hagedorn and Jenson's (5) method for determination of larger quantities of reducing sugars.

SAMPLING AND PRESERVATION

Material from different experiments was sampled at random on specific dates. When taking samples of leaves, three first fully emerged leaves were taken arbitrarily from each row of a plot excluding the border rows. For the whole plant sample, only two plants were dug out, one each from any two rows of a plot excluding the border rows. In all cases samples were taken in the morning. The samples were killed by keeping them within half an hour of their collection in an electric oven maintained at a temperature of 100°F.—110°F. for three to four hours. This period was sufficient to kill the enzymes of the tissues. They were then thoroughly dried at 90°C. to 95°C., powdered and preserved in packets for future analysis.

OBSERVATIONS

1. Study of the effect of age on sugarcane metabolism

For these studies variety Co. 313 was selected. Monthly samples of the whole plant were taken from a plot which did not receive any additional manure excepting a basal dressing of *sana'i* (*Crotolaria juncea*) green manure. Leaf, leaf-sheath and stem were analyzed separately for nitrogen and carbohydrate fractions. The analytical results for the leaf as averaged for three consecutive seasons are detailed in Table I.

TABLE I

Nitrogen and carbohydrate fractions in the leaf of Co. 313 (average of three years)
(per cent dry weight)

Items	April	May	June	July	August	September	October	November	December	January	February
Total N	1.5760	1.7440	1.7147	1.4627	1.1017	1.0460	.9165	.8900	.6505	.6545	.7410
Crystalloid N	.3054	.2745	.2737	.2593	.2312	.2050	.2250	.2279	.2142	.2505	.2042
Protein N	1.2706	1.4695	1.4410	1.2034	.8705	.7501	.6915	.6621	.4363	.4040	.5368
Amino N	.0417	.0252	.0268	.0236	.0135	.0215	.0254	.0144	.0119	.0228	.0180
Amide N	.0800	.0250	.0611	.0481	.0501	.0761	.0695	.0483	.0541	.0846	.0876
Total sugars	3.83	6.16	4.59	5.38	4.59	5.28	8.05	5.04	8.06	6.96	7.24
Invert sugars	1.89	2.37	1.43	1.21	1.73	1.83	1.97	1.65	2.82	2.31	2.02
Sucrose	1.95	3.79	3.16	4.17	2.86	3.45	6.08	3.39	5.24	4.65	5.22
Crystalloid per cent of total N	19.37	15.74	15.96	17.72	20.98	28.29	24.56	25.61	32.94	38.27	27.55

Leaf.—It will be seen from the above table that *total nitrogen* is high upto June which is the period of high metabolic activity in the plant. It begins to fall after this month and the decline is gradually maintained till harvest. The fall may be attributed to age effect and is quite independent of weather conditions. *Protein N* follows the same trend as the *total N*. It appears that the fall of total N is mainly due to decreased protein synthesis as the plant ages. *Crystalloid N* which represents the soluble N fraction shows slight proportionate increase when expressed as percentage of *total N*. This increase may partly be due to increased hydrolysis of proteins, resulting in the accumulation of lower soluble nitrogenous compounds.

Amino N is high in April, but gradually falls off in the following months, slightly rising again towards the end period. *Amide N* is high in April but falls upto August after which it rises again slightly and falls in November and December, with a slight rise in the end. The behaviour of these two fractions is more or less erratic, but nevertheless high values in the beginning and towards the end may indicate that they first synthesise into protein building material and form protein hydrolysis products at the end. *Total sugars* are high in the beginning but remain more or less constant till November after which there is a slight rise which is maintained till the end. The behaviour of invert sugars and sucrose very much resembles that of the *total sugars* viz., high in the beginning and then showing a slight rise again at the end.

The data for the nitrogen and carbohydrate fractions in leaf-sheath are shown in Table II.

TABLE II

Nitrogen and carbohydrate fraction in the leaf-sheath of Co. 313 (average of three years)
(per cent dry weight)

Items	April	May	June	July	August	September	October	November	December	January	February
<i>Total N</i>	1.0860	.9400	1.2860	.7765	.4965	.4740	.4260	.4335	.4045	.3690	.3120
<i>Crystalloid N</i>	.3741	.3502	.3006	.2533	.1648	.1804	.1859	.1898	.1655	.1464	.1437
<i>Protein N</i>	.7119	.5898	.9854	.5232	.3316	.2936	.2400	.2437	.2389	.2226	.1683
<i>Amino N</i>	.0666	.0404	.0390	.0249	.0092	.0082	.0123	.0153	.0207	.0130	.0076
<i>Amide N</i>	.0593	.0323	.0601	.0342	.0498	.0234	.0395	.0458	.0428	.0487	.0585
<i>Total sugars</i>	4.36	4.85	11.22	9.93	7.39	5.92	7.20	11.76	21.39	13.01	9.58
<i>Invert sugars</i>	3.76	.133	4.88	3.50	3.85	3.82	3.60	3.85	4.17	4.54	3.30
<i>Sucrose</i>	.60	3.52	6.34	6.44	3.53	2.10	3.60	7.91	17.22	8.47	6.28

Leaf-sheath.—From Table II which shows averages for leaf-sheath, it will be seen that the behaviour of nitrogen fractions is very much the same as in leaf, the only difference being that the absolute values of total and protein N are less in this component of the plant. The trend of total sugars is also similar to that in the leaf; but the absolute values are much higher. Invert sugars and sucrose follow the trend of *total sugars*. The data for nitrogen and carbohydrate fractions in stem are shown in Table III.

TABLE III

*Nitrogen and carbohydrate fraction in the stem of Co. 313 (average of three years)
(per cent dry weight)*

Items	April	May	June	July	August	September	October	November	December	January	February
Total N	..	1.2740	1.2590	.9960	.4360	.2890	.2970	.2380	.2740	.2810	.1670
Crystalloid N	..	.6579	.6171	.3923	.2060	.1705	.2035	.1710	.2116	.2345	.1270
Protein N	..	.6161	.6419	.6037	.2300	.1185	.0935	.0670	.0624	.0465	.0400
Amino N	..	.1737	.1319	.0428	.0136	.0107	.0170	.0229	.0323	.0371	.0183
Amide N	..	.1224	.1312	.0647	.0489	.0411	.0624	.0501	.0658	.0829	.1002
Total sugars	..	3.56	9.13	14.93	15.99	20.39	29.25	28.90	39.38	4.793	32.15
Invert sugars	..	1.03	2.15	5.72	12.05	11.24	8.29	5.12	3.79	6.86	2.27
Sucrose	..	2.53	6.98	9.21	13.94	14.61	20.79	23.78	35.59	27.93	29.88
Crystalloid per cent of total N	..	51.04	49.03	39.39	47.25	68.98	68.52	71.85	77.21	83.45	76.05

Stem.—From the above it will be seen that the trend of total N and protein N is the same as in the leaf and leaf-sheath viz., high in the early stages and decreasing subsequently. Their absolute values are, however, very low. Crystalloid N increases with age and its values when expressed as percentage of *total N* are much higher than either in the leaf or leaf-sheath. It is interesting to note that in the stem there is preponderance of crystalloid N. This is evidently due to the nitrogen being stored in the soluble form in the stem which is a storage organ. Unlike the green leaf or leaf-sheath, amino and amide N are fairly high in the stem during the early stages. This period synchronises with that of vigorous growth and rapid protein synthesis, *i.e.*, the tillering period of the plant. After this period both these fractions show a fall upto September, subsequently showing again a slight rise. This rise is not apparently due to active protein synthesis, but may partly be due to the accumulation of protein degradation products at the end of the plant life. It is clearly established from the above data that proteins are gradually disappearing from the stem and are being replaced by soluble nitrogen fractions which are comprised mostly of amino and amide N.

Total sugars, as calculated on dry weight, go on increasing from the early stages to the harvest. It will be seen that nitrogen and carbohydrate content in the stem

are inversely correlated, *i.e.*, with the fall of nitrogen content the carbohydrate content increases. Invert sugars increase upto September and then begin to fall. From this month onward the increase of sucrose is very rapid. Sucrose very much follows the course of *total sugars*.

2. Study of the effect of yellowing in sugarcane leaves

For the last two or three years yellowing of leaves has been observed in the crop during the months of August and September. It has been definitely established that this phenomenon does not occur due to the incidence of any fungus disease or pest. In order to understand the metabolic differences between the healthy and yellow plants, a sample each of healthy and yellow plant was analyzed for nitrogen and carbohydrate contents. Leaf and stem of both the types were analyzed.

From the Table IV which gives averages of three years for leaf and two years for stem it will be seen that both total and protein N are more in the leaf of healthy than in that of the yellow plant, showing thereby that yellowing reduces protoplasmic content in green parts. This is further corroborated by the preponderance of amino and amide N in yellow over healthy leaves which indicates that yellow leaves abound in protein degradation products. The same is true in the case of stem also. Total and protein N are more in the healthy stem and the protein degradation products such as amino and amide N are more in the stem of yellow plant.

TABLE IV

Nitrogen and carbohydrate fractions in the leaf and stem of healthy and yellow plants in the month of September (per cent dry weight)

Items	Average of 3 years		Average of 2 years	
	Healthy leaf	Yellow leaf	Healthy stem	Yellow stem
Total N	·9293	·7644	·3620	·3120
Crystalloid N	·2412	·1993	·2188	·2041
Protein N	·6881	·5651	·1381	·1082
Amino N	·0198	·0240	·0100	·0125
Amide N	·0385	·0726	·0246	·0786
Total sugars	5·99	7·91	25·02	33·07
Invert sugars	1·67	2·69	9·00	14·27
Sucrose	4·32	8·55	16·01	18·80
Sucrose per cent of total sugars	..	..	64·00	56·85

Total sugars are on the other hand more in the yellow plant both in the leaf and the stem. It cannot, however, indicate increased photosynthetic activity because from the analysis of nitrogen fractions it has been seen that yellowing causes destruction of living protoplasmic matter. The increase of total sugars may be due to two reasons.

1. Translocation machine in the leaf is disturbed. This is borne out by the fact that total sugars in yellow leaf are nearly double of that in the green leaf. In the stem the difference is not so marked.

2. Yellow plants react to the adverse circumstances and perhaps tend to ripen early, and this increase may be due to early ripening.

It will be interesting to note that although *total sugars* and *sucrose* are more in the stem of yellow than in the green plant, *sucrose* expressed as percentage of *total sugar* is less in the case of the former. *Invert sugars* are also more in the yellow plant. It may indicate partial cessation of the process of elaboration from lower to higher sugars due to yellowing.

3. Preliminary observation on the effect of *pyrilla* infestation on the metabolism of *sugarcane*

A sample each of *pyrilla* free and infested leaves was taken from a field heavily affected by *pyrilla* at Gorakhpur Farm. As usual the samples were analyzed for nitrogen and carbohydrate fraction to understand differences, if any, between the metabolism of the two types of leaves. It is intended to continue this study whenever the *pyrilla* attack is severe again.

TABLE V

Nitrogen and carbohydrate contents in pyrilla free and infested leaves, August 1945 (per cent dry weight)

	<i>Pyrilla</i> free leaves	<i>Pyrilla</i> infested leaves
<i>Total N</i>	1.0550	.9000
<i>Crystalloid N</i>	.1964	.2171
<i>Protein N</i>	.8586	.6829
<i>Amino N</i>	.0203	.0209
<i>Amide N</i>	.1108	.0582
<i>Total sugars</i>	5.43	4.67
<i>Invert sugars</i>	1.15	2.21
<i>Sucrose</i>	4.28	2.46

Table V shows the different fractions in the two types of leaves. A comparison of the two will show very interesting results. It will be seen that both total and protein N are more in the healthy than in the pyrilla infested leaves indicating thereby that in some way pyrilla partly inhibits protein formation. It is further supported by the presence of more crystalloid N in pyrilla infested leaves than in the healthy ones. It appears that lower nitrogenous compounds are not fully utilized in elaboration of proteins and therefore accumulate in quantity. Although amino N is nearly equal in the two, amide N is more in the healthy than in the yellow leaf. The role of amide N is not very clear in this case.

Total sugars and sucrose are also more in the healthy leaves than in the infested leaves. Pyrilla, therefore, not only partly inhibits protein elaboration process but also appears to destroy sugars in leaf. Presence of high glucose values in the infested leaves further supports the view that although the basal material (reducing sugars) for elaboration of higher sugars is there, pyrilla reduces part of the higher sugars so formed by sucking it.

SUMMARY

The following tendencies seem to be clearly indicated from the above experiments :

1. There is more of *total nitrogen* in leaf, followed by leaf-sheath and stem.
2. *Total nitrogen* goes down with age in all the parts.
3. During the later part of the plant life, there is greater accumulation of soluble nitrogen (crystalloids).
4. In the stem soluble nitrogen predominates. In the later part of the plant life *total nitrogen* in the stem is mostly in the form of crystalloids.
5. Amide nitrogen content is always higher than amino nitrogen. This is specially true when the plant grows old, showing thereby that amide nitrogen is the main hydrolysis product of proteins in sugarcane.
6. *Total sugars* in leaves go up with age.
7. Yellowing diminishes protein content and increases *total sugar* content in leaf and stem.
8. Pyrilla attack diminishes both nitrogen and sucrose content in leaf.

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AGRICULTURAL PROBLEMS OF THE TUNGABHADRA IRRIGATION PROJECT, MADRAS PRESIDENCY

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THE four districts of Bellary, Anantapur, Kurnool and Cuddapah, comprising the Ceded Districts of the Madras Presidency, are subject to frequent famines of varying magnitude, due to their peculiar geographical situation in the South Indian Peninsula. The rains received are erratic both in incidence and magnitude and it has been the experience of the tract that out of 70 years on record, 34 years had suffered from deficiency of rainfall. The tract receives on an average a rainfall of 22.89 inches. The most satisfactory solution to avoid famine and ensure good crop-growth in this zone is to harness the water from the Tungabhadra which forms the boundary between Madras and Bombay in one stage and Madras and Hyderabad at another stage of its course, and utilise the water for irrigation. On the Madras side, nearly 0.26 lakhs of acres are already under wet cultivation where paddy, sugarcane etc., are cultivated for the past several years. The Government of Madras in consultation and in co-operation with the Hyderabad State Government have started constructing a dam across the Tungabhadra near Hospet (Bellary District). The reservoir is estimated to supply about 50 thousand cubic feet of water per year to each territory.

The scheme is intended to benefit a large extent of the tract by providing irrigation to crops that are normally cultivated under rainfed conditions. The tract receives both south-west and north-east monsoons and during the former period termed locally as *mungari* (*kharif*) crops like *jonna* (Sorghum), *korra* (*Setaria italica*), cotton, groundnut and pulses are grown on the light black and red soils. In the north-east monsoon period termed locally as *hingari* (*rabi*), cotton, *jonna*, Bengal-gram, safflower and wheat are grown on the heavy black soils. About 80 per cent of the project with a commanded area of 2.5 lakhs of acres in parts of Bellary and Kurnool Districts, consists of black soils. It is proposed to give light irrigation of about two inches depth, once a fortnight, for a period of four months, either in *hingari* or *mungari* seasons. Provision will also be made for wet lands 'garden lands' and orchards in the project area. The distribution of cropping will be as follows :

Under 'dry-crop irrigation'	192,000 acres (4 months supply)
Under 'wet lands' and 'orchards'	51,000 acres (8 months & perennial)
Under 'garden lands'	7,000 acres (8 months)
<i>Total</i>	250,000 acres

The success of irrigating black soil has often been questioned. It is often asked why very little use is made of the water from the Cuddapah-Kurnool Canal which runs through the black soil tracts. The failure of the Nira Valley Project in the Bombay-Deccan, where alkalinity developed in the black soils, as a result

of irrigation is cited as an example. The possibility of development of alkalinity in the project area is examined during the soil survey conducted in 1934-35 by the Agricultural Department with special reference to sub soil and bed rock. The conclusion arrived at were, that the soils could be successfully irrigated without developing alkalinity provided (a) proper drainage is assured and (b) a system of distribution is devised to prevent indiscriminate use of water. Another great advantage noticed was that the water of the Tungabhadra contained a very low percentage of salt (·007 to ·027 per cent). It was found quite safe to be used for irrigation.

TRIALS CONDUCTED ON THE AGRICULTURAL RESEARCH STATION, SIRUGUPPA

Nearly 80 per cent of the tract consists of black-soil and it was classified by Ramiah [1937] into four groups, viz., (i) deep soils (more than three feet) with gypsum; (ii) deep soils without gypsum; (iii) shallow soils (less than three feet) with gypsum and (iv) shallow soils without gypsum. The soils were found to rest on a layer of white *kankar* (disintegrated granite) locally known as *garasu*. The black soils of the tract are rich in clay and have high water holding capacity with low permeability. The percentage of silts is low in the top three feet in concentrations not injurious to crop growth. They are chiefly composed of gypsum, sodium chloride and sodium sulphate. Shallow soils form about 20 per cent of the project area and are mostly situated near water courses termed locally as '*vanka*'. The main object of starting the Agricultural Research Station, at Siruguppa was (a) to test the adverse effect if any, in irrigating the black soils and (b) to fix suitable crops for raising in different seasons. The chemical and agronomic studies pursued are dealt below.

Chemical studies

The black soils of the project area have low salt content in the top three feet of soil [Ramiah, 1937]. It was feared that when the application of water is restricted only to crop growth period and left unirrigated in summer, an accumulation of salts in the profile, especially in the upper layers may be felt in course of years. To test whether such increase in salt content does take place in the top profile investigations were carried in deep and shallow black soils, receiving light or copious irrigation. Since the data obtained from the samples drawn prior to irrigation, after harvest of the crop, and in summer, did not show any appreciable difference during the several years examined, only summer samples were considered in the present study. The data of the samples when the land was brought under irrigation and those collected after several years of irrigation were compared. In the case of deep black soils, data was also collected from three irrigation treatments and compared with the control (unirrigated). In this study the soils were not ploughed or manured throughout the experimental period. Cotton and *jonna* were grown in rotation during the *hingari* season. In the case of shallow soils ploughing and manuring were done every year but irrigation was restricted to once a fortnight. In addition, samples were examined from profiles with gypsum and without gypsum. In the case of shallow soils receiving copious irrigation (wet-lands) heavy manuring

and ploughing was done every year. Paddy and sugar-cane were grown in these blocks. The percentages of soluble salts estimated at different depths in the various cases mentioned above are given in Table I.

TABLE I

Showing the percentage of total soluble salts on air-dry basis in different depths of different kinds of black soils receiving varying intensities of irrigation

Serial number	Treatment	Sampling date	Depth of soil				
			First foot	Second foot	Third foot	Fourth foot	Fifth foot
1	No irrigation	1939	0.08	0.09	0.13	0.59	0.71
		1944	0.07	0.09	0.12	0.18	0.64
2	Restricted irrigation in deep soils receiving no manure						
		1939	0.08	0.09	0.11	0.14	0.33
		1944	0.07	0.10	0.10	0.13	0.23
		1939	0.08	0.09	0.10	0.15	0.61
		1944	0.08	0.09	0.11	0.14	0.30
		1939	0.08	0.10	0.12	0.22	0.69
		1944	0.07	0.09	0.10	0.42	0.22
3	Restricted irrigation in shallow soils manured every year. (2½ tons of farm yard manure + 50 N as groundnut cake)						
		1943	0.08	0.09	0.42	..	..
		1946	0.09	0.12	0.20	..	..
		1943	0.12	0.20	0.44	..	..
		1946	0.07	0.13	0.28	..	..
4	Copious irrigation in shallow soils heavily manured every year. (6 tons of green leaf + 40 lb. of N. as groundnut cake and ammonium sulphate + 20 lb. of P_2O_5 as bone meal)						
		1940	0.10	0.50	1.11	..	..
		1945	0.10	0.21	0.17	..	..

It is seen that in no case an increase in percentage of salts in course of years as compared with the respective initial samples is felt. On the other hand, in the case of gypseous soils and in samples drawn from the lower layers which had higher salt content, a fall in values is noted.

Agronomic studies

The main lines of investigations made under this item were studies (i) on the effect of mere irrigation, (ii) on the effect of early and late sowing, (iii) manurial trials, (iv) trial of crops and varieties suitable for the black soils under irrigation and (v) on the duty of water.

(I) *Studies on the effect of mere irrigation.* The rainfed crops are not normally manured. It was therefore planned to know the effect of mere irrigation on these crops. No appreciable increase in yield was obtained in any of the crops as seen in Table II.

TABLE II
Yield per acre in pounds

Serial number	Treatment	Jonna (local yellow) Mungari season						Korra (local) Mungari season			Cotton (Hagari.1.) (<i>G. herbaceum</i>) Hingari season		
		1939-40		1940-41		Mean		1939-40	1940-41	Mean	1938-39	1939-40	Mean
		Grain	Straw	Grain	Straw	Grain	Straw	Grain yield only			Seed—cotton yield		
1	Rainfed	497	1153	304	808	401	981	363	498	431	340	425	383
2	Irrigated	682	1737	218	1037	450	1387	404	242	323	330	403	367
	C. D. at 5 per cent level	Not significant	Not significant	Not significant	229	..	..	Not significant	Not significant	..	Not significant	Not significant	..

(II) *Studies on the effect of early and late sowing.* In this trial also no manuring was done to the crops, but they were irrigated. The results of the investigations are given in Table III.

TABLE III
Showing the results of the time of sowing experiment conducted with various crops on the Agricultural Research Station, Siruguppa

Serial number	Treatment	Jonna (local) Mungari season			Korra (local) Mungari season			Groundnut (A.H. 25) Mungari season			Cotton (Hagari.1.) (<i>G. herbaceum</i>) Hingari season		
		1939-40	1940-41	Mean	1938-39	1939-40	Mean	1938-39	1939-40	Mean	1938-39	1939-40	Mean
		Grain yield only			Pod yield only			Seed—cotton yield					
1	Early	682	218	450	616	404	510	1022	1732	1377	330	403	367
		1737	1037	1387									
2	Late	221	167	194	195	274	235	632	1051	842	325	237	281
		2771	1374	2073									
	C. D. at 5 per cent level	Not significant	Not significant	..	..	..	..	..	..	..	..	..	..
		Not significant	80	..	283	Not significant	..	283	543	..	Not significant	Not significant	..

N.B.—In the case of Jonna numerator denotes grain yield and denominator straw yield

It is seen that though the yields of the crops are poor, the beneficial effect of early sowing is seen in all cases. In another set of experiments conducted with M.A.II cotton (*G. hirsutum*), at a later date in the *hingari* season of 1946-47, where the crop was manured at 80 N-level in the form of groundnut cake and 30-N and 40 P₂O₅ in the form of ammonium phosphate, the following results were obtained :—

YIELD OF SEED COTTON PER ACRE IN LB.

Time of planting

1 August	15 August	1 September	15 September	C. D. at 5 per cent level
1193	1302	810	215	249

Conclusion. It is seen that the yields of cotton sown in the month of August are definitely superior to those sown in September.

From the above investigations it may be concluded that mere irrigation of black soils will not be helpful to improve the yields of crops and other factors, like 'time of sowing,' manuring, etc., will have to be considered.

(III) *Manurial trials.* Investigations were conducted on irrigated H.A. 11 cotton, during three *hingari* seasons (1942-43, 1943-44 and 1944-45), with three nitrogen levels, viz., 0 N, 40 N and 80 N, in suitably replicated randomised blocks. Nitrogen was applied in the form of green manure, farm yard manure and groundnut cake. The results are given in Table IV. For the sake of brevity, only the effect of nitrogen levels is considered in the present paper.

TABLE IV

*Manurial experiments**Main yield of kapas per acre in pounds*

Variety H.A. 11 Cotton

	1942-43	1943-44	1944-45	Mean
1. No manure	483	261	127	290
2. 40 N	672	531	344	516
3. 80 N	738	766	511	672
C. D. at 5 per cent level	73	45	53	..
<i>Conclusions</i>	3, 2, 1	3, 2, 1	3, 2, 1	

It is seen that manured plots give higher yield than unmanured plots and that 80 N level is superior to 40 N level from the point of yield.

Investigations conducted in 1946-47 with *jonna* and cotton gave the following results with different levels of nitrogen and phosphates :-

(a) 'JONNA'

Yield per acre in lb.

Serial number	Manurial doses	Variety	Grain	Straw
1	0 N	A.S. 7437	913	5300
2	30 N	"	1654	6974
3	60 N	"	2244	7106
	C. D. at 5 per cent level	..	460	1196

Conclusions :

Grain 3, 2, 1
Straw 3, 2, 1

(b) 'JONNA'

Yield per acre in lb.

(Variety A.S. 2095)

Serial number	Manurial doses	Grain	Straw
1	30 N and 20 P ₂ O ₅	2802	9231
2	30 " 40 "	2978	9972
3	60 " 20 "	3242	9670
4	60 " 40 "	3488	10907
5	90 " 20 "	3434	10357
6	90 " 40 "	3654	10687
	C. D. at 5 per cent level	110	225

Conclusions :

Grain 6, 4, 5, 3, 2, 1
Straw 4, 6, 5, 2, 3, 1
N applied in the form of groundnut cake and 'ammophos'
P₂O₅ " " " " " ammophos only

*American Cotton**(Variety H.A. 11)*

Serial number	Manurial doses	Kapas (seed cotton)
		Yields per acre in lb.
1	60 N & 30 P ₂ O ₅	1529
2	60 " 60 "	1772
3	80 " 30 "	1675
4	90 " 60 "	1723
5	120 " 30 "	1796
6	120 " 60 "	1893
	C. D. at 5 per cent level	111

Conclusions:

6, 5, 2, 4, 3, 1

N applied in the form of groundnut cake and 'ammophos'

P₂O₅ " " " " " " 'ammophos' only

In both the crops response of yield with increased doses of manures is seen.

(IV) *Trial of crops and varieties suitable for the black soil under irrigation.* Since 1943 a number of crops were tried under irrigation both in the *mungari* and *hingari* seasons. The details are furnished in Table V.

TABLE V

Showing crops raised in large scale plots at the Agricultural Research Station, Siruguppa on black soils with their yields, economics, etc.

Successful crop	Suitable variety	Growing season		Yield per acre in pounds		Cost of cultivation per acre including land taxes and water rates	Net profit per acre
		From	To	Grain	Straw		
American cotton	H.A. 11	September	March	767 (kapas)	..	Rs. 77	Rs. 73
Jonna	A.S. 2095	June	September	1,172	4,518	59	83
Korra	K. 132	June	September	911	1,521	59	33
Groundnut	Local bunch	June	September	802 (pods)	..	93	33
Wheat	Local	October	January	1,026	..	84	83

TABLE V—*contd.*

Showing crops raised in large scale plots at the Agricultural Research Station Siruguppa on black soils irrigation with their yields, economics, etc.—concl'd.

Successful crop	Suitable variety	Growing season		Yield per acre in pound		Cost of cultivation per acre including hand taxes and water rates	Net profit per acre	
		From	To	Grain	Straw			
Maize	Yellow (Coimbatore)	{ June October	September January	1,000	3,500	63	as a mixture with crown orra and groundnut K 7 7	
Red gram	2232	June	February					500
Ragi	E. C. 393	June	October	1,704	4,323	87		83
Onion	Dhulla	October	January	10,000	..	157	113	
Chillies	Guntur 396	June	December	808 (dry fruits)	}	..	107	193
	Adoni	September	March	200 (dry fruits)				
Paddy	G.E.B. 24	July	November	2,701	4,570	130	140	
Sugarcane	Co. 419	February	January	27 (tons of cane)	..	412	433	

It is seen that in addition to the rainfed crops of the tract other new crops like, wheat, *ragi*, maize could be raised successfully in the project area.

Cultural trials. In the Tungabhadra Project, it is proposed to supply water once fortnight for a period of four months in the year to facilitate *mungari* and *hingari* cropping. Water for the *mungari* season will be supplied from June to the end of September and for the *hingari* season from October to the end of January. The cultural trials conducted indicate the possibility of raising crops on the black soils both in the *mungari* and *hingari* seasons. The crops found suitable for the *mungari* season are *jonna*, *korra*, *ragi*, chillies, maize and groundnut and for the *hingari* season, cotton, wheat, maize, and chillies. In the above system cotton in the *mungari* and *jonna* in the *hingari* season could be grown successfully. The cultivators have to lose one of the above two important crops. A trial was made to rotate the cropping by treating the same land as *mungari* in one year and as *hingari* in the following year. The chief defect noticed in this method was that there was a long gap of about eleven months when a land cropped in the *mungari* season was next cultivated only in the *hingari* season. The land was unnecessarily left fallow for a considerable period. When the process was reversed there was a very short gap of only two months by cultivating the land in *mungari* season and cultivating it again in the *hingari* season. This system does not allow sufficient time for the various operations of preparatory cultivation.

A trial was made to investigate the possibilities of growing two crops in the same land in one year by supplying water for eight months. It was found that if water is supplied for eight months it is possible to raise in proper season and get remunerative yields. Either before or after harvest of the main crops, one can raise sunn hemp in June and plough it in August, and the cotton can be sown in September. Similarly after sowing *jonna* in July and harvesting the same in October, one can raise Bengal-gram crop or a green manure crop and plough it in by end of January.

Wet land cultivation is already in existence in the project area. In Siruguppa village, nearly, 3,000 acres are under cultivation with crops like sugarcane and paddy. Paddy and sugarcane were tried on the station. In the case of paddy, strain G. E. B. 24 and in sugarcane Co. 419 were grown. The agronomic trials on paddy were confined to growing (1) single crop and (2) double crop. In the case of single crop, planting was done in July and the crop was harvested by the middle of December, while in the case of double crop where two short duration varieties were tried, viz., A.D.T. 3 and Co. 8 the planting of first crop was done in June and harvested by end of September and the second crop was planted by the end of October and harvested by end of January. Observations recorded that in the case of double crop paddy the first year's response was good, but in later years, the yield of both the crops went down considerably as seen below.

DOUBLE CROP PADDY TRIALS

Yield per acre in lb.

	1942-43		1943-44		1944-45	
	Grain	Straw	Grain	Straw	Grain	Straw
First crop (A.D.T. 3)	3039	3939	2760	2613	1323	2116
Second crop (Co. 8)	2174	2745	1623	2549	Failed	

In rotation trials sugarcane and paddy were cultivated in alternate years. Paddy gave an average yield of 2,563 pounds of grain and 4,152 pounds of straw, and sugarcane 26 tons of cane.

(V) *Studies on the duty of water.* The duty of water for irrigating crops was calculated by the following formula :

$$\text{Duty of water} = \frac{(a \times b \times c)}{d + e}$$

Where

'a' is period of crop growth in days.

'b' no. of hours, water was flowing daily to irrigate the crop during the growing period.

'c' area of the field irrigated.

'd' total acre inches of water applied as measured by 'V' notch.

'e' 2/3 of the total quantity of rainfall received during the growing period.

The average duty worked for various crops is as follows :

Crops	Average duty for five years (including rainfall)
<i>Mungari-jonna</i>	163
<i>Hingari cotton</i>	265
<i>Ragi</i>	126
Wheat	234
<i>Korra</i>	103
Groundnut	156
Paddy	60
Sugarcane	90

Dry crops (mean duty 175)

Wet crops (mean duty 75)

Period of water supply

Thirumali Ayyangar [1942], in his report has estimated the supply of water available for irrigation, including evaporation losses as follows :

Months	Cusecs	Metric cubic feet
1. June—October	1,800	18,663
2. October—February	1,800	18,663
3. February—June	600	6,221
<i>Total</i>	4,200	43,547

Since nearly the same figures have been accepted by Raghavan [1946], in his report there is no difference of opinion between the two as regards the available supply of water. On the assumption that water received from rains would supplement the requirements of the crops either for earlier cultural operations or for further growth of the crop both the officers mentioned above have suggested supply of water for four months only in both the seasons. The area estimated to be brought under irrigation is therefore, considerable.

Since the tract is subjected to frequent failure of rains, the idea of depending on rains is not a sound one in a scheme designed for the successful and assured production of crops. An assured supply of water up to the final stages of crop growth is essential. As already stated restricting water supply to four months is beset with serious difficulties and many of them could be easily overcome if water is given for eight months. The points that are against restricting the supply to four months and

those that are in favour of eight months supply will have to be considered carefully before a final decision regarding the distribution of water is fixed.

The points for consideration are as follows :

Four months irrigation. (1) For the *mungari* season (June to September), it has been recommended that water need not be supplied after September and the crops if necessary can get on with the 'fair' amount of rainfall, normally received in August, September and October. Under the project conditions water is let into irrigation channels in June and it takes more than a fortnight to reach the tail end. Experience has shown that the cultivators will start preparatory cultivation only after the receipt of water and not earlier. As such the sowing will naturally extend from about the middle of June to about the middle of July and the harvest of most of the crops will be over only by about the end of October. Hence, irrigation water will have to be given till the end of October and not till the end of September, as programmed.

In this connection, it is worthwhile to mention the experience gained in the Bhagavadi Farm, which is about five miles from Siruguppa where water is given free to watch the reactions of the cultivators, when the project matures. From the records maintained by the special staff or the Agricultural Department stationed in this village the information regarding the cropping calendar adopted is mentioned below :

Crop	1944-45		1945-46		1946-47	
	Sowing	Harvest	Sowing	Harvest	Sowing	Harvest
(a) <i>Jonna</i>	2 July	22 October	28 June	21 October	9 June	30 September
	1 August	13 November	9 July	28 October	12 June	22 October
(b) <i>Korra</i>	6 July	22 October	23 July	29 October	..	..
	30 July	10 November	..	..	..	..
(c) <i>Chillies</i>	..	..	15 July	29 September	24 June	19 September
	..	..	6 August	13 February	19 July	23 February
(d) <i>Ground nut bunch type</i>	..	..	22 July	25 October	16 June	23 September
	..	..	27 July	7 November	24 June	21 October
(e) <i>Maize</i>	..	..	..	..	13 June	10 September
	..	..	..	..	24 June	17 September

It is observed that the sowing of *mungari* crops generally extends up to the end of July, while the harvesting is up to the end of October. This clearly indicates that water in the *mungari* season is required up to the end of October.

Regarding the *hingari* season where water is programmed to be supplied from October to end of January trials conducted have shown that cotton, when sown late suffers adversely in yield but when sown in August and September gives remunerative yield. Water should therefore be made available in the *hingari* season from August.

If water is given only in October the choice of crops will be restricted. Only wheat, Bengal-gram, maize, vegetables and onions could be grown successfully. Instead of supplying water to the cultivators for four months in *mungari* and four months in *hingari* season, continuous supply of eight months from June to January will be advantageous as detailed below :

(1) The cultivators will be assured of a continuous supply of water, without the fear of supply being cut off at the fag end of the crop, involving serious disaster.

(2) The cultivators will have a wide choice of crops to grow and diversified farming could be adopted.

(3) There will be sufficient scope to grow green manure crops and plough it in the soil. This will be the most practical and cheapest way of building up the soil fertility of the vast tract proposed to be irrigated in the absence of sufficient supply of cattle manure. The addition of organic matter will improve the 'tilth' and drainage of the black soil.

(4) With eight months supply of water the combinations of crops that could be raised are indicated below :

Crops	From	To	Duration
1. Ladies finger and tomatoes	{ June September	August-September January	3½ months 5 "
2. Korra and Cambodia cotton	{ June September	August-September February	3½ " 6 "
3. Ragi and onion	{ June October	October February	4½ " 4½ "
4. Maize and cotton	{ June September	August-September February	3½ " 6 "
5. Groundnut bunch and maize and	{ June September	August-September November-December	3½ " 3½ "
Green manure and or fodder	December	February	3½ "

Crops	From	To	Duration
6. Chillies	June	January	7 months
7. Groundnut (bunch) and Cambodia cotton	June	August-September	3½ "
	September	February	6 "
8. Groundnut (bunch) and gloomed wheat	June	September	3½ "
	October	February	6 "

The tract has very thin population (167 per sq. mile) and the economic condition of the *ryot* is very poor; besides, labour and livestock are inadequate. Under these conditions it is highly problematical whether the proposed 2.5 lakhs of acres could be brought under cultivation with the restricted supply of irrigation in both seasons. On the other hand, if the area is reduced and continuous supply of water is assured for eight months there are greater chances of the entire area being brought under intensive cultivation immediately.

If a continuous supply of water for eight months is assured for the wet lands, there is a good opportunity for increasing the production of pulses. A long duration paddy giving higher yield than the short duration ones, could be grown from June to November followed by a pulse crop from November to February.

SUMMARY

The Government of Madras in co-operation with the Government of H. E. H. the Nizam of Hyderabad, has taken up the construction of a dam across the Tungabhadra to launch an irrigation project to protect part of the area in Bellary and Kurnool Districts, in the Madras Presidency, and part of the area in Hyderabad State, frequently affected by famine.

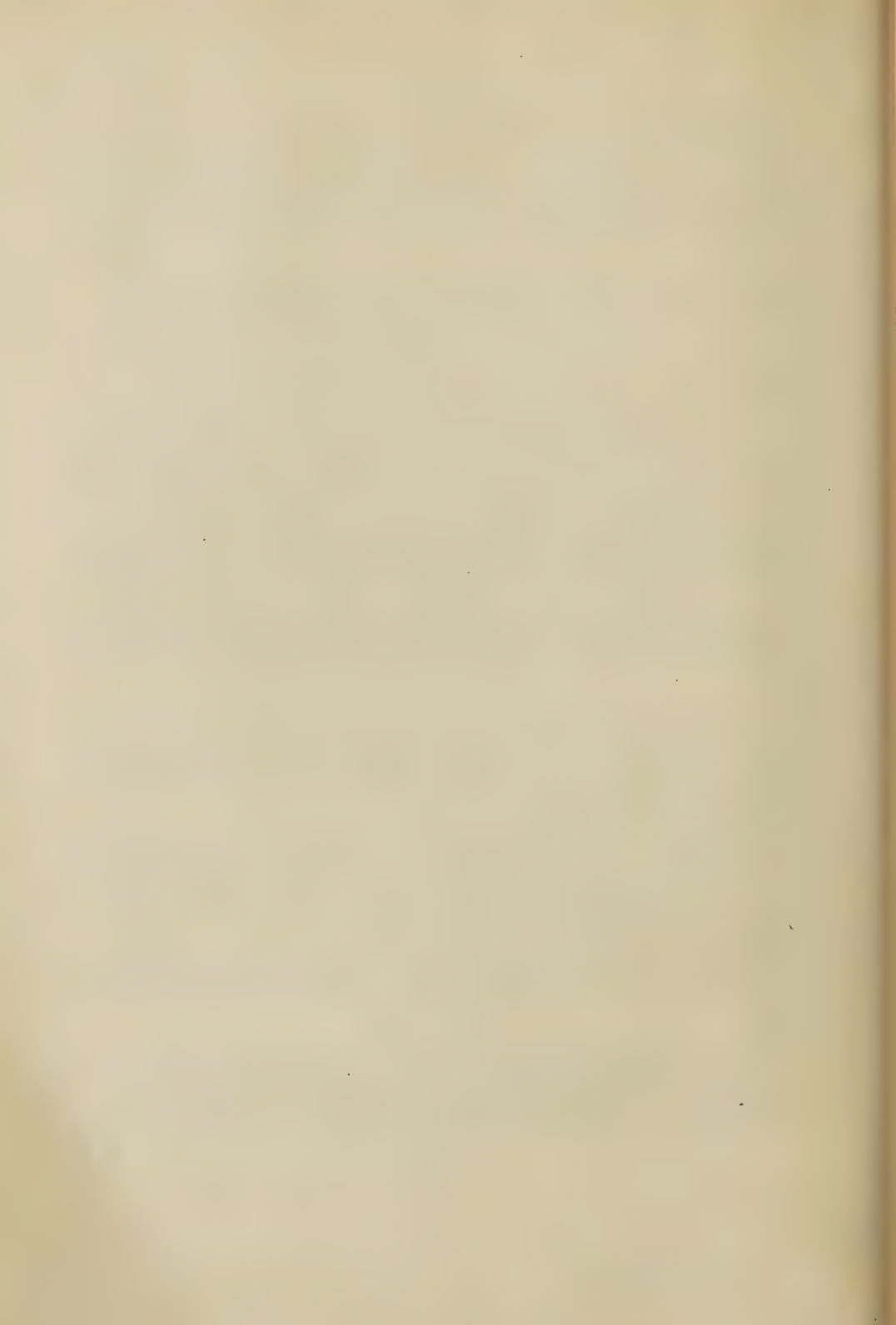
Experiments conducted at the Agricultural Research Station, Siruguppa have indicated that the injurious salts present in the black soils get washed down with irrigation and there is no upward rise of salts due to evaporation of soil moisture.

Crops that could profitably be raised in both seasons viz., *mungari* (June to October) and *hingari* (October to January) have been fixed.

There is clear evidence to indicate that it is desirable to supply water for irrigation purpose from June to January instead of restricting them to four months in either season.

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INFLUENCE OF SOME OF THE ENVIRONMENTAL FACTORS ON THE YIELD OF GREEN FODDER AND SEED IN BERSEEM IN THE PUNJAB

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BERSEEM (*Trifolium alexanderinum*), an excellent fodder crop, though not indigenous to this country, has come to occupy a position of great eminence in the farm economy of the irrigated areas of the province. According to the latest figures available, collected through the courtesy of the Deputy Directors of Agriculture in the Punjab, 266,075 acres were put under it in 1944-45. These figures, however, do not represent the actual state of affairs, as most of the records of the area of winter fodder crops like *senji* (*Mellilotus parviflora*) and *shaftal* (*Trifolium resupinatum*) are mixed in it. Area under the crop would expand enormously, but the supply of adequate quantities of good seed is a great limiting factor in its wide spread cultivation. The demand to some extent is met by importing it from the N.-W. F. P. but in this case its cost is so high that it is beyond the means of the average farmer to purchase it. Berseem is capable of giving very high yields of green fodder in four to five cuttings from November to May under suitable environments, and the fodder is highly nutritious and palatable. This fact is evident from the percentage of various constituents, revealed through chemical analysis given below.

Chemical analysis of berseem of five cuttings of green fodder

Cut	Ash	Fat	CF	Protein	N.F.E.	HCl soluble ash	CaO	P ₂ O ₅	K ₂ O ₅	Mn ₃ O ₄
1st cut	19.03	1.29	24.49	17.44	37.75	16.31	3.75	0.46	5.91	.0174
2nd cut	15.27	1.45	27.62	12.87	22.79	14.23	3.55	0.29	4.54	.000
3rd cut	20.12	1.47	8.87	12.0	47.56	15.26	4.06	0.52	4.86	.00086
4th cut	16.43	1.79	27.27	11.94	42.57	15.92	3.22	0.45	5.17	.00030
5th cut	14.52	2.40	26.73	11.20	45.15	12.0	2.63	0.69	3.74	.0058

Berseem is a highly restorative crop, not only for improving the fertility of the soil on which it is grown, but has also shown great superiority over other crops in reclaiming alkaline soils.

With the growing knowledge and popularity of berseem as an ideal winter fodder crop, great difficulty began to be experienced for the supply of adequate quantities of its good seed to the cultivators of the Punjab. The seed, as mentioned above, was mostly imported from the N.W.F.P., which in addition to being extremely costly, contained a lot of chicory (*Chicorium intybus*) seed. Even the Department

had no other course than to arrange for berseem seed from that province. The cultivators also rightly or wrongly, began to believe that N.-W. F. P. seed was superior to that raised in this province, because of the favourable climatic conditions obtaining there; but this alone could not be taken as a very strong reason for ruling out the possibility of raising good berseem seed in this province.

As in other crops, it is generally to be anticipated that the behaviour of imported seed is likely to be somewhat different in a new habitat, because of the great variation in the temperature, rainfall and soils of different localities. The aim of the present investigation was, therefore, to study the extent of variation in yield when berseem was raised from seed imported from the N.-W. F. P., in comparison with the crop raised from seed produced in the Punjab.

Berseem is a modern fodder crop which has the prospects of extensive expansion but adequate and up-to-date knowledge regarding its various agronomic aspects, based on the results of definite experiments, is very limited. With a view to obtain reliable data, as a part of the study of the experiments designed to determine the influence of source of seed on yield, effect of the following factors was included in the present investigation :

1. Influence of date of sowing on yield.
2. Influence of the interval between two successive cuttings on yield.
3. The suitability of some other crops for growing mixed with berseem for augmenting its yield of fodder from the first cutting.
4. Influence of the time, at which the crop is left to mature seed, on its yield of seed.

Influence of source of seed on yield of berseem

Climate is the most important single factor, which restricts the limits within which a crop can be successfully grown. Though there are wide differences in the soil and climatic conditions, such as temperature, rainfall and altitude of the Punjab, and the N.-W. F. P., berseem seed had to be imported at a very high cost from that province, because good quality seed was not available in the Punjab. The heavy cost of its seed was, however, a great limiting factor in its large scale expansion in the irrigated areas of the Punjab. The problem of producing berseem seed in this province, therefore, was very urgent. With this end in view, extensive experiments were conducted at the Fodder Station, Sirsa from 1939 to 1945 to see if good quality berseem seed could be raised in the Punjab, and to compare the performance of seeds raised in the N.-W. F. P. and in the Punjab, both for outturn of fodder and yield of seed.

REVIEW OF LITERATURE

A number of investigations have been reported in the literature, on the extent of variation in the yield of different crops, as a result of the influence of source from which the seed was obtained, but none has been reported in the case of berseem. Schafer *et al* [1921] reported slight variations in the yield from a comparison of Washington and Manitoba wheats at Washington, the former being superior, yielding

41.12 bushels, and the latter yielding 40.62 bushels per acre. Sprague [1935] reported that varieties of corn, introduced from other States, were almost invariably inferior to the well adapted local strains. Bayles [1936] found significant variation in yield in only three out of 91 individual seed lots, produced under different environmental conditions, from other seed lots of the same variety.

As a result of the studies of various experiments in Europe, Piper [1937] reported that locally grown seeds gave better yields than those brought from a distance. In the United States this phenomenon was well-known in the case of highly bred crops like corn, but was not recognized to any great extent in the case of grasses and clovers. He ascribed the higher yields of crops raised from local seeds to their adaptation and acclimatization, and elimination of inferior individuals. In plots of orchard grass, grown side by side in Virginia, the New Zealand strain was distinctly shorter and apparently inferior by about 20 per cent. Under Swiss conditions Stebler found French seed to be the most satisfactory, and the American seed only slightly inferior, though it was late. Seeds from Switzerland, Holland and Germany gave in each case practically as good results as those from France, while the New Zealand strain proved inferior to others.

Tests conducted for a period of three years to determine the amount of hay produced from seed from different sources, namely, the United States, Denmark, Germany, France, Sweden, Australia, New Zealand, at three experimental stations in Denmark, showed that American strain was superior to the European at the two stations; while Australian and New Zealand gave smaller yields by about 20 per cent.

As regards the influence of source of seed on alfalfa, it was concluded by Piper that the best results were as a rule secured from locally grown seeds, provided there was no difference in variety. Investigations conducted in Germany and France, regarding the relative behaviour of plots sown respectively with seed of American and European alfalfa from different sources, indicated that yield of hay from American seed was the best, and that it was also more subject to mildew than the European.

Similar experiments in America showed that in general Southern grown seeds were not favoured in more Northern regions, because they were inferior to cold resistance.

Ulrich *et al* [1944] reported insignificant variations in sugar-beet production by growing it under different climatic conditions at two locations, with the same seed and fertilizer, and attributed the differences in production to climatic conditions.

It is apparent from the various references mentioned above, that source of seed has very little influence on yield, and it is more due to the climatic conditions that variation in yield is observed.

MATERIAL AND METHODS

The experiments herein reported were planned to determine the effect of source of seed on yield of green fodder and seed, and were conducted at the Fodder Research

Station, Sirsa, in the South East Punjab from 1938-39 to 1944-45, viz., for a period of seven years. Similar experiments were conducted at some other Agricultural Stations also.

The average annual precipitation at Sirsa is approximately 10 in. of which about 1.5 in. occurs during the crop growing season from September to April-May. Drought frequently occurs, however, and is perhaps the chief limiting factor to otherwise successful crop production in that locality—as a matter of fact in the whole of the Punjab.

Berseem seed was imported from two different places, Peshawar and Bannu with almost similar conditions of climate in the N.-W. F. P. and from a number of places in the Punjab, viz., Montgomery, Multan, Gurudaspur, Sargodha and Lyallpur, representing varied conditions in the irrigated areas of the province.

The experiments to study the influence of source on the yield of green fodder and ripe seed, were conducted according to the randomized system of field trials in blocks varying from six to eight in number and each block consisting of three to eight ecotypes of berseem. The size of unit sub-plots varied from 1/40th to 1/80th acre. During 1939-40, however, one experiment at Sirsa was arranged according to the Latin Square System with six ecotypes and six repeats in unit sub-plot of 1/100th acre. The seed used in these experiments was of the Mescavi variety only, which has been found to do comparatively much better than other varieties usually available in Egypt. The rate of seeding normally varied from eight to twelve seers per acre, and sowings were carried out at the normal sowing time, that is, in the end of September or early October by broadcasting inoculated seed in standing water.

The yields of green fodder and seed, obtained from these tests, were analyzed statistically and the results were considered significant when 'F' value exceeded the expected values at one per cent and five per cent levels of significance.

To start with in 1938-39 comparisons of the N.-W. F. P. and Punjab berseem seed, both as regards yield of green fodder and seed, were under way at Sirsa and Lyallpur, where the crop raised from Punjab seed gave higher outturn of fodder and seed; but later on experiments were extended and conducted at various Departmental Agricultural Stations, except Rawalpindi, in order to obtain definite data regarding the behaviour of these seeds under varied conditions.

DISCUSSION

It is well-known that good quality berseem seed is bright yellow, while poor quality seed contains brown and immature seeds also. The seed obtained from different sources was, therefore, analyzed into its components on the basis of colour of seed, viz., yellow, yellow-brown, brown and immature, etc., both as regards weight of these components and the number of seeds in each. The requisite analysis of seeds on the basis of ten grams weight of each sample for the two years 1939-41, is given in Table I.

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GREEN FODDER AND SEED IN BERSEEM IN PUNJAB

TABLE I
Analysis of seed obtained from different sources on the basis of 10 gm. weight

Source of seed	1939-40					Per cent germination	1940-41				
	Yellow	Yellow brown	Brown	Immature	Total		Yellow	Yellow brown	Immature	Others	Total
1. Sirsa	{ Weight 556 Number 1965 }	307 1163	0-30 127	1-07 578	10-0 3753	{ 79 }	{ 0-850 2634 }	2-305 1145	0-250 288	0-595 ..	10-0 4067
2. Montgomery	{ Weight 520 Number 1591 }	372 1239	0-68 230	0-40 89	10-0 3149	{ 89 }	{ 4-220 1432 }	3-885 1387	0-200 288	0-760 41	10-0 3579
3. Multan	{ Weight 457 Number 1688 }	310 1165	0-83 325	1-50 643	10-0 3821	{ 81 }	{ 5-200 1837 }	3-620 1370	0-9100 361	0-229 17	10-0 3690
4. Jhang	{ Weight 575 Number 2100 }	268 946	0-52 190	1-05 667	10-0 3893	{ 77 }	{ .. .. }	.. ..	.. ..	.. ..	.. ..
5. Sargodha	{ Weight 848 Number 2376 }	247 822	0-40 144	0-65 265	10-0 3607	{ 84 }	{ 4-430 1363 }	3-670 1271	1-900 376	0-555 nil	10-0 3253
6. Gurdaspur	{ Weight 646 Number 2508 }	1-97 734	0-20 82	1-37 828	10-0 4125	{ 81 }	{ 5-950 1083 }	3-000 1132	0-330 144	0-320 nil	10-0 3417
7. Risalewala	{ Weight .. Number .. }	.. ..	.. ..	.. ..	.. ..	{ 89 }	{ 5-000 1633 }	3-735 1283	0-880 329	0-185 nil	10-0 3283
8. Hansi	{ Weight .. Number .. }	.. ..	.. ..	.. ..	.. ..	{ 75 }	{ 2-180 768 }	3-815 1603	2-485 1541	0-720 nil	10-0 4225

TABLE I.—*contd.**Analysis of seed obtained from different sources on the basis of 10 gm. weight*

Source and seed	1939-40				Per cent. germination	1940-41				Total	Per cent. germination	1940-41				Total
	Yellow	Yellow-brown	Brown	Immature		Yellow	Yellow-brown	Brown	Immature			Yellow	Yellow-brown	Brown	Immature	
9. Jullundur	Weight	..	..	..	{	4.150	1.550	nil	1.065	{	..	4.150	1.550	nil	1.065	{
	Number	..	..	..		1584	648	nil	1050			1584	648	nil	1050	
10. Delhi	Weight	..	..	..	{	5.800	3.400	0.180	0.320	{	81	5.800	3.400	0.180	0.320	{
	Number	..	..	..		1983	1582	211	173			1983	1582	211	173	
11. Peshawar	Weight	6.29	2.40	0.36	{	6.650	1.620	0.42	0.160	{	88	6.650	1.620	0.42	0.160	{
	Number	2223	879	131		2393	650	198	100			2393	650	198	100	
12. Bannu	Weight	6.07	1.81	1.27	{	..	..	..	..	{	89	..	..	..	..	{
	Number	2171	682	489		..	..	..	..			..	..	..	..

The analysis given in Table I shows clearly that there is great variation in the different components, viz., yellow, yellow-brown, brown and immature seeds in the various samples. During 1939-40, Gurdaspur and Sargodha samples had the highest weights (6.46, 6.48 gm.) and numbers (2508 and 2376) of yellow seeds; Peshawar and Bannu samples were close seconds as their weight and numbers were 6.29 and 6.07 and 2223 and 2171 respectively. It is indicated that seed superior in quality to the N.W.F.P. seed could be raised in some parts of the Punjab. In the year 1940-41, Sirsa seed had the highest weight, 6.86 gm. and 2634 yellow seeds per 10 gm. of the seed samples and Peshawar sample was a close second with 6.65 gm. weight and 2393 grains, while there was very little difference in samples obtained from other parts of the province. Hansi sample had the least weight (2.180 gm.) and number (783) per ten gm. The climate and availability of irrigation water at the flowering and seed setting time have a determining influence on the development and maturity of seed, and good quality seed can be raised in some parts of the Punjab in good years. These seeds were sown for conducting the comparative fodder and seed yield tests. The results obtained are given in Table II.

TABLE II
Mean yield of green fodder from berseem raised from seed obtained from different sources
Acre yield in maunds and seers
Sources of seed

Year	Experimental Station	N.-W.F.P.			Punjab					Significance at	
		Peshawar	Bannu	Sirsa	Montgomery	Multan	Lyalpur	Gurdaspur	Sargodha	1 per cent	5 per cent
1939-39	Sirsa	904.20	958.20	810.0	1002.0	nil	nil	nil	nil	14.12	10.31
1939-40	Sirsa 1	838.0	996.0	953.0	988.0	1002.0	nil	1070.0	1048.0	7.79	5.83
	Sirsa 2	695.0	762.0	842.20	nil	nil	812.20	nil	nil	11.50	8.43
	Sargodha	371.0	nil	nil	330.0	nil	nil	nil	336.0	Not significant	
1940-41	Montgomery	681.0	nil	822.0	708.0	..	..	..	..	15.14	10.23
	Sirsa	510.0	548.0	520.0	516.0	nil	544.0	648.0	530.0	18.74	13.97
	Montgomery	589.0	..	616.0	652.0	nil	648.0	..	..	Not significant	
	Hansi	478.16	..	527.16	..	..	..	..	..	13.9	9.17
	Lyalpur	226.0	..	..	..	..	248.0	..	..	Not significant	
1941-42	Multan	702.2	..	758.8	..	703.21	..	..	..	Not significant	
	Sirsa	803.0	..	822.0	729.0	..	..	790.0	667.0	14.28	10.05
1942-43	Montgomery	320.0	..	371.0	366.0	..	311.0	..	..	Not significant	
	Gurdaspur	317.24	..	323.8	..	..	..	..	..	Not significant	
1942-43	Sirsa	986.0	910.0	1089.24	1080.0	..	..	1022.0	1028.24	Not significant	
1943-44	Sirsa	1090.16	..	1281.24	1339.20	..	1155.8	1392.0	1235.8	82.61	0.50
1944-45	Sirsa	937.0	..	1032.0	1043.0	..	1068.0	1064.0	1027.0	t	t

TABLE III

Mean yield of seed in maunds and seers per acre from berseem seed obtained from various sources at different Experimental Stations

Year	Experimental Station	N.-W.F.P.		Punjab							Critical differences at	
		Peshawar	Bannu	Sirsa	Montgo- mery	Multan	Jhang	Lyallpur	Gurdaspur	Sargodha	1 per cent	5 per cent
1938-39	Sirsa	1-2	1-39	5-0	9-27	nil	nil	nil	nil	nil	1-13	0-38
1939-40	Sirsa	0-1	0-1/2	2-18	1-0	0-24	1-15	nil	0-25	0-18	0-44	0-34
1939-40	Sirsa	0-2	nil	nil	nil	nil	nil	1-9	..	..	0-42	0-3-6
1940-41	{ Lyallpur Sirsa	0-35	nil	nil	nil	nil	nil	10-28	..	..	..	..
		0-6	nil	2-22	2-17	nil	nil	2-28	2-9	2-11	0-34	0-25
1941-42	Sirsa	5-29	nil	12-9	11-5	nil	nil	nil	11-25	10-10	12-4	9-1
1942-43	Sirsa	0-28	nil	6-33	6-14	nil	nil	nil	7-7	7-12	20-3 Significant	14-9 Significant
1943-44	Sirsa	2-28	nil	7-8	8-24	nil	nil	7-36	7-36	8-0	2-11 Significant	1-52
1944-45	Sirsa	5-18	nil	11-12	13-6	nil	nil	13-5	10-34	8-8	2-67	2-03
	Total Average	16-79	2-0	48-16	52-13	0-24	1-15	35-24	40-16	37-9	..	..
		1-32	2-0	6-2	7-19	0-24	1-15	7-5	6-29	6-8	..	..

Reviewing the results of experiments given in Table II, it is apparent that out of sixteen experiments, results of eight were significant and in favour of the locally produced seed. In the remaining eight experiments, though differences in yield of green fodder of crops raised from the two different sources were not significant, yet they were invariably higher in the case of local seed. The highest yields of green fodder were recorded at Sirsa in 1943-44, when the crop from Peshawar seed yielded 1090 maunds per acre, and that from the Punjab seed gave an outturn of 1339 maunds per acre.

Results of seed yield trials given in Table III also show conclusively the superiority of local seed over the N.-W.F.P. seed. In all nine tests have been reported and in all cases results were highly significant and in favour of local seed. In the year 1944-45, when seed setting was very good in berseem crop the highest yield 13 maunds 6 seers of seed was obtained from the local seed crop as compared to five maunds 18 seers from the Peshawar seed crop. The plants from Peshawar seed are rather spreading in nature and have comparatively more tillering capacity. On this account and on account of their long growing period in the N.-W. F. P. the Peshawar and Bannu seeds are capable of giving one light cutting of green fodder in addition as compared with the Punjab crop, but this can happen only under favourable conditions of irrigation and season. The total yield of green fodder, however, is practically the same in both cases. To substantiate the statement made above a partial summary of results obtained during the year 1940-41 is given below :

Place of comparison		Yield per acre of green fodder from		Differences in favour of Punjabi or Peshawari seed	Yield of seed per acre from	
		Punjab seed	Peshawar seed		Punjab seed	Peshawar seed
		Maunds	Maunds	Maunds	Maunds Seers	Maunds Seers
1.	Jullundur	913	800	+ 113	..	..
2.	Multan	764	702	+ 62	..	..
3.	Montgomery	652	589	+ 63	..	..
4.	Sirsa*	584	470	+ 114	2 22	0 6
5.	Hansi	527	473	+ 54	..	..
6.	Lyallpur†	248	226	+ 22	10 28	0 34
7.	Gurudaspur	207	173	+ 34		..

* Sirsa crop was allowed to mature seed after 3 cuttings of green fodder.

† Crop was allowed to mature seed after two cuttings.

The yields vary very much both from year to year and from one Experimental Station to another. During 1939-40, the yields were poor at the Fodder Research Station, Sirsa, but were very encouraging during 1940-41 and 1944-45, from which it can be concluded that it is more due to the favourable climatic conditions that good setting in berseem can be obtained, than to anything else. If some showers of rain are received during the winter season in February, March and April, which tend to keep the season mild, and the temperature somewhat below 100°F., the setting is very good, and as a result high yields of seed are obtained; but in the absence of winter rains, when hot and dry winds begin to blow early in the season, and irrigation water is also available in limited quantities, setting is adversely affected, resulting in very low yields of seed.

The source of seed had a very remarkable influence on the yield of seed of the two crops, viz., those raised from the N.-W.F.P. and the Punjab seeds. The former as is mentioned above, is more tillering and late flowering than the Punjab crop. The result is that the periods of development of flowers and seed synchronize with the hot season, which invariably starts from the end of April, and thus adversely affects both, and consequently results in low yields of seed. It may, therefore, be inferred that the crop from the Punjab seed is superior, and gives higher yields of seed than the crop raised from the N.-W. F. P. seed.

Taking the results of the seven years collectively, it is apparent that the N.-W. F.P. seed yielded about 1 maund 32 seers to 2 maunds seed, while the Punjab seed gave as high as seven maunds of seed per acre, which is a very good average yield of berseem seed.

In view of this, it has been definitely proved that berseem seed can be raised successfully in some tracts of the Punjab, and that this seed is superior to the N.-W.F.P. both as regards green fodder and seed production.

2. Influence of date of sowing on yield

The optimum time of sowing of crops has come to be established as a result of long experience, and in the case of berseem, which is a newly introduced crop, it has been found to extend from the end of September to early October in the Punjab. But there is no definite experimental data to indicate the best sowing time and the extent of variation in yield, when sowings are made at different times during this period, or they are delayed on account of some factors beyond the control of the farmer. Work to some extent has been carried out at some of the departmental Experimental Stations, but systematic studies to find out how differences in yield express themselves in relation to varying times of sowing, have been very limited. The various environmental factors have a definite influence on the physiological activity of the plant, which in turn influences yield.

Extensive studies have been reported regarding the influence of date of sowing on yield of crops, but very few have been reported in the case of berseem. Some preliminary experiments carried out at the Indian Agricultural Research Institute, New Delhi in 1940-41, showed that the best yield was obtained from a crop sown on October 15. The other dates in order of merit were October 1, November 1,

December 1 and 15 and November 15. Usually authors agree that yield decreases as the sowings are delayed. Engledow and Ramiah [1930] noticed remarkable effect of late sowing on yield in wheat, and attributed the differences to the influence of season. Adair [1940] and Hadeyet Ullah [1944] found consistent reduction in yield with delayed sowings. That yield of wheat was adversely affected by late sowings was reported by Singh and Alam [1944] also. From some of these instances it will be apparent that time of sowing is a very important factor determining yield in crops. The present investigation was, therefore, conducted to find out definitely the most suitable time for sowing berseem in order to get maximum yield.

Mescavi variety of berseem, which has been found to do well in our climate, was sown at varying intervals from the middle of September to the middle of November, during the last four years from 1942-1946 at the Fodder Research Station-Sirsa. The experiment was conducted in randomized blocks with unit subplots of 1/45th acre, keeping three dates of sowing, in six repeats. The size of the unit plot varied in other years. It was 1/55th in 1943-44 and 1944-45 and 1/72th in 1945-46 and sowing dates were increased to four in 1943-44 and five in 1944-45 and 1945-46. Similar dates could not be kept in the successive years 1944-45 and 1945-46 because of the late running of the canal. The crop was sown with inoculated seed in standing water with the usual seed rate of ten seers per acre. It was, however, not possible to stick to the same dates of sowing every year, because sowings were controlled to a great extent by the availability of canal water. The cuttings of green fodder were taken as and when the crop was ready. Table IV shows the total yield of fodder obtained from varying sowing dates in the year 1942 to 1946.

TABLE IV

Mean yield of green fodder per acre in maunds when berseem is sown at varying intervals

Year	Dates of sowings					Significance per cent C.D.
	10/9	17, 18/9	24,25/9	1/10	11/10	
1942-43	..	1235	1165	1172	..	Not significant 1 per cent 5 per cent 117.65 77.32
1943-44	1088	1339	1203	1301	..	Significant 15.45 10.9
1944-45	883	1243	1507	1287	1155	Significant 67.57 48.19
	11/10	20/10	24/10	5/11	13/11	.. ..
1945-46	442	448	405	401	317	Significant 40.75 29.93

Yield of green fodder per acre is of prime importance in berseem and any increase in it is a direct gain to the cultivator. It is rather the most complex physiological character, being the result of a number of interacting environmental factors. Total yield of green fodder per acre, in berseem, obtained from a number of cuttings, as shown in Table IV, indicated, that sowings made at weekly intervals during the second fortnight of September up to the 1st week of October, viz., 17/9, 24/9 and 1/10, have given the highest outturns, as compared with sowings, either carried out earlier, or later than these dates. Each sowing represents a particular set of environmental conditions, which are likely to have a great influence on the germination and stand, and consequently vegetative growth of the crop. The season, due to very high temperature in the very early sowing, is adverse for good germination and uniform stand of the crop. Moreover, the crop in the very early sowings is also dominated to a very great extent by the rank growth of weeds, and this hinders normal development of berseem seedlings. In sowings made later than the beginning of October, the growth period is decreased, thereby causing reduction in the number of cuttings of green fodder, and thus reduction in its total yield. The different conditions influence the physiological conditions of the plant, their relative influence varying with the time of sowing.

It will also be observed from the table that yields of green fodder were exceptionally high in 1942-43 and fairly low in 1945-46. Though high yields in 1942-43 were due to initial soil fertility of the Fodder Research Station, Sirsa, the season had a tremendous influence on the growth of the crop. Winter of 1945-46 passed absolutely dry which resulted in the early advent of hot and dry winds, which influenced very adversely the yield of green fodder and seed.

Since seed setting depends upon the time at which the crop is last cut for green fodder, this aspect has been dealt with separately.

3. *Influence of the intervals between two successive cuttings on yield of green fodder*

Berseem is capable of giving a number of cuttings of green fodder during its growing period. The period taken by the crop to become ready for cuttings, varies with the season, fertility of the soil and the availability of irrigation water. Instances have been noticed, where seven to eight cuttings of green fodder have been obtained under a system of good farm management, yielding invariably more than 1000 maunds per acre. Naturally in such cases the crop becomes ready for cutting in about thirty days or so. But cases are not infrequent when berseem crop has made such poor growth as to give hardly two or three cuttings of green fodder, yielding 300 to 400 maunds per acre only. Though the number of cuttings and yield will be controlled by the factors mentioned above, it is necessary to know, as to what is the desirable stage of growth, when the crop cut will not only give the highest outturn in that cutting, but will also allow its subsequent quick growth. With this end in view, an experiment was conducted in randomized blocks in six repeats at the Fodder Research Station, Sirsa in 1944-45 and extended to other farms in 1945-46 by keeping twenty, thirty, forty, fifty and sixty days intervals between two successive cuttings. Sowings were carried out with common Mescavi variety, as usual with inoculated

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seed, broadcasting it in standing water. The mean yields per acre obtained during two years under varying intervals are given in Table V.

TABLE V

Mean yield of green fodder per acre under varying intervals between the two successive cuttings

Mean yield per acre in maunds

Year and station	Cutting intervals in days					Significance at	
	20	30	40	50	60	1 per cent	5 per cent
1944-45							
Sirsa	410	683	925	1006	1003	40	50
1945-46							
Sirsa	318	620	668	574	448	58	115
Gurdaspur	512	944	960	992	704	338	245
Multan	506	784	813	838	673	73	53
Hansi	439	609	618	508	501	64	47

Earlier in 1941-44 similar tests were conducted at Lyallpur Agricultural Station with the following results :

Mean yield per acre in maunds cutting intervals (days)

Year	15	30	45	60
1941-42	212	298	719	660
1942-43	350	366	523	589
1943-44	346	659	1016	965

Berseem makes luxuriant vegetative growth under favourable conditions of soil and moisture, and takes about a month or so to become ready for successive cuttings after the first cutting. This period, however, varies under different conditions. From the yield of green fodder obtained under varying intervals between two successive cuttings, it can be definitely concluded that 40 days interval is the best, yielding on an average 800 maunds per acre. These results confirm the earlier trials conducted at Lyallpur, where 45 days interval was found superior to others. Khan and Singh [1946] concluded that very low yields of green stuff were obtained in either 15 or 30 days cutting intervals, because high frequency of cutting affected adversely the sprouting capacity of the crop, and as a result a considerable number of plants dried up early in the season. They also did not favour the cutting

interval of 60 days, because by that time fodder became very fibrous and developed some unpleasant odour, as a result of which fodder was not relished by cattle. It can, therefore, be recommended that cutting interval in berseem, should in no case exceed 50 days, while highest return can be expected, when cuttings are taken at intervals of 40 days.

4. *Influence of the time at which crop is left to mature seed on its seed yield*

There are conflicting opinions as to the most suitable time at which the berseem crop should be left to mature seed. It is claimed in certain quarters that the crop, when left after taking second cutting in February, sets very good seed, some consider middle of March to be the optimum time from the economic point. Sayer [1935] reported that good seed was formed at all farms in the Punjab. The number of cuttings to be taken before the crop was left to form seed varies with the fertility of the soil, last cutting being taken preferably by the first week of March or by the middle of March at the latest. Still others think that beginning of April also is not even late for good seed setting. As a matter of fact this period is also primarily controlled by the vagaries of season and availability of irrigation. In the N.-W. F. P., where the growing season is long and remains very favourable for seed setting up to the end of June, the crop is left in the end of April, and yet sets very bright yellow seed; but in the Punjab the season becomes fairly hot, and the crop left at that time gives very low yields of poorly developed and immature seed. In order to establish the most suitable time for this purpose, experiments were conducted at the Fodder Research Station, Sirsa, and other farms in the year 1943-46. The sowings of these experiments were conducted as usual in replicated randomized blocks in unit sub-plots of 1/55th acre and six repeats with inoculated seed of Mescavi berseem at the optimum sowing time. The yields of seed, obtained under a system of varying dates of cutting, after which crop was allowed to mature seed, are given in Table VI.

TABLE VI

Mean yield of berseem seed per acre, keeping varying dates of last cutting (in maunds and seers)

Year	Station	Dates of last cutting				Significance at	
		15/2	1/3	16/3	31/3	1 per cent	5 per cent
1943-44	Sirsa	9.23	8.27	3.32	3.18	0.36.7	0.26
1944-45	Sirsa	11.13	12.5	12.25	8. 7	1.2	0.30
1945-46	Sirsa	0.22	0.29	1.17	1.27	0.39	0.28
	Gurdaspur	2.8	3.20	2.32	2. 7	0.19	0.14
	Hansi	2.32	1.38	1.10	0. 1	..	2.14
	Multan	2.15	1.37	1.30	1. 8	Not significant	
	Montgomery	3.9	2.23	2.10	2.28	Not significant	
	Total	20.30	19.14	13.10	11. 9	..	..

The yield of seed of any crop is the ultimate result of all the physiological activities of the plant, which are controlled by a number of factors. Among them temperature, humidity, fertility of the soil and availability of irrigation at the seed setting time, are the most important. The length of growing period, which is also determined by the temperature, is another limiting factor in successful seed setting. It is apparent from the yield of seed obtained after taking the last cutting at varying times during 1944-45, at the Fodder Research Station, Sirsa (Table VI) that earlier the crop was left to mature seed, higher was the yield of bright yellow and plump seed. Yield, however, decreased as the date of last cutting for green fodder was delayed. This was probably the most favourable season for seed setting, because very high yields were secured even after the last cutting on 31 March. But yields of seed were very low during 1945-46 at all the departmental farms, where this experiment was conducted. The seed setting season in this year remained absolutely dry, and the low humidity resulted in early advent of hot season, which in turn influenced both setting and development of seed. The setting was very low and the seed remained shrivelled. It can, therefore, be concluded that the crop left after the beginning of March gave satisfactory yields; but in case irrigation water is not available at the flowering and seed setting periods, crop left earlier may also give lower yields than the crop left late in the end of March.

The low yield of seed in berseem is not due to the season alone, which varies to a very great extent from the middle of February to the end of March, because it gradually becomes hot and dry, but also depends upon the number of visiting insects, which is also highly reduced in the month of April and May, when crop left late in the season is in full bloom. Bees and particularly honey bees, which are the primary agents concerned in the pollination of berseem flowers, multiply and remain active during the mild season of February and March, and their activity is considerably reduced in the month of April and May. Even in the mild season berseem would not set seed if these insects are not allowed to visit the flowers. Earlier work conducted in this connection showed fairly conclusively that berseem would not set seed more than 0 to 2.5 per cent, if inflorescences are bagged and insects are not allowed to visit the flowers. The effect of hot and dry season, therefore, firstly to retard the growth by reducing the number of tillers per plant and the number of inflorescences, and secondly to reduce the number of bees, and thus decreasing the extent of fertilization of flowers. The lower number of inflorescences coupled with lower pollination and withering of a large number of flowers, results in very low yields of seed from the crop, left to mature seed late in the season. From the economic point of view, however, the additional cutting of green fodder taken compensates for the low yield of seed in this case.

5. Suitability of some of the non-legumes for growing mixed with berseem for augmenting its yield in the first cutting

Berseem plant, to start with has a single stalk and a very few tillers, and it is after the first cutting that it tillers profusely; consequently the total amount of green stuff is much lower in the first cutting than in the subsequent cuttings. Moreover, green fodder is very scarce from the end of October to early December, because

kharij fodder crops are over, and *rabi* fodder crops are not ready for harvesting. It is only the early sown berseem which becomes ready for first cutting in about the middle of November, but its yield is low because of low tillering in the early stages. In earlier stages, therefore, it would allow other crops to grow along with it. To find out which crop can be raised along with it to augment its yield during the first cutting without affecting the subsequent growth, experiments were conducted in randomized blocks with five repeats in unit sub-plots of 1/80th acre each, by comparing the crop grown alone, with berseem sown mixed with other *rabi* crops such as *rapes* (*Barssica campestris* Var. *Napus*), *oats* (*Avena sativa*) and *Senji* (*Mellilotus parviflora*) for a period of four years from 1942-1946. The sowings were carried out at the proper sowing time by broadcasting the mixed seed in standing water, keeping in view the proportion of different seeds mixed with berseem. Growth was fairly satisfactory in all cases, but *rapes* grew more quickly than others due to their inherently quick growing character, while *oats* and *senji* having long growing periods, grew slowly and were not able to make as much growth as *rapes*, and consequently added comparatively little green stuff to the first cutting of berseem. But to obtain definite data, experiments were conducted, and the yields obtained are given in Table VII.

TABLE VII

Mean yield of green fodder per acre in maunds from berseem sown alone and in mixture with other crops

Year	Station	Berseem alone	Berseem and rape	Berseem and oats	Berseem and senji	Significance C.D.	
						1 per cent	5 per cent
1942-43	Sirsa	1112	1400	1286	1200	Significant 25-25	18-12
1943-44	Sirsa	1334	1665	1445	1325	Significant 183-34	134-25
1944-45	Sirsa	1145	1224	1141	1130	Not significant 117-8	85-8
1945-46	Sirsa	614	718	597	..	Significant 78-31	57-27

The yields obtained definitely point out to the superiority of *rapes* in augmenting the tonnage of green stuff of berseem in its first cutting, which is due to the leafy quick growth of this crop as compared with other crops. It is, therefore, definitely concluded that *rape* is the best crop that can be sown mixed with berseem for increasing its yield in the first cutting.

SUMMARY

Berseem (*Trifolium alexanderinum*), Var. *Mescavi*, which has adapted itself to the climatic conditions of this country, was grown for a study of the influence of some of the environmental factors on the yield of green fodder and seed. The experiments were laid out in the randomized block design at the Fodder Research Station, Sirsa and some of the departmental Experimental Stations.

Yield of green fodder is not influenced to any appreciable extent by the source of seed. Crops raised both from the Punjab and the N.-W. F. P. seeds gave almost equal yields under favourable environmental conditions. The differences were significant in a few experiments only, and in most cases yields obtained showed that they were not due so much to the influence of the source of seed as to the effect of climatic conditions and availability of irrigation in the locality.

The source of seed had a very remarkable influence on the yield of seed of the two crops. The plant from the N.-W.F. P. seed is more tillering and later flowering than that from the Punjab seed. As the seed setting period of the former synchronises with the hot season during April and May, the development of seed is adversely affected, resulting in poor setting and shrivelled seeds. The data of seven years indicated that the Punjab seed is much superior to the N.-W. F. P. in seed this respect, the former yielding on the average seven maunds, while the latter giving an outturn of 1.75 maunds to two maunds of seed per acre.

In view of these conclusions, it has been established that good berseem seed can be raised in the Punjab under irrigation, and that this seed is as good as that from the N.-W. F. P. for raising a crop of green fodder, while it is much superior so far as seed production is concerned.

The period from the third week of September to early October is the best for sowing berseem in order to secure the maximum tonnage of green fodder. Sowings made earlier than this become highly infested with weeds, and sowings later than this give low yields of fodder due to decrease in the number of cuttings.

Maximum yield of green fodder is obtained if 40 days interval is kept between two successive cuttings. This is closely followed by 50 days interval.

The crop gives good outturn of bright yellow and plump seed, if it is allowed to mature seed after taking the last cutting by the end of February or the beginning of March. Cuttings taken after this reduce the growing period of the crop and seed setting season synchronises with the hot and dry season, which result in the reduction of the number of inflorescences and number of honey bees, and thus influence both seed setting and seed development.

Rape has been found to be the most suitable non-legume for sowing mixed with berseem in order to augment its yield in the first cutting.

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PRELIMINARY OBSERVATIONS ON THE BIONOMICS OF POTATO TUBER MOTH (*GNORIMOSCHEMA OPERCULELLA* ZELL.) AND ITS CONTROL IN BIHAR, INDIA

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THE problem of storage of potatoes has been drawing the attention of various workers in India since 1907. Lefroy [1910] described durations of different stages of the potato tuber moth (*Gnorimoschema operculella* zell.) and its fecundity and recorded that the eye-buds are the points of infestation and recommended storage of potatoes in thin layers under sand mixed with naphthalene or charcoal. Woodhouse and his colleagues [1911-13] confirmed these findings and found that dipping of potatoes for five minutes in crude oil emulsion before storage, increased rots in storage. Mann, Nagparkar and Kasargode [1920] recommended cold storage and fumigation of the tubers with carbon-bisulphide. Vyas [1930] recommended storage of potatoes under cinder or charcoal. Helson [1942-44], in Australia, found dusting of the tubers with magnesite (20 lb. per ton of potatoes) in the store and spraying with phenothiazine (one lb. per gallon of water) for protecting the potato crop from the infestation of the moth in the field, satisfactory. Lloyd [1943-46] in New South Wales, found two per cent DDT dusting suitable for reducing the moths' infestation on plants in the field and on seed-tubers in the stores. Cannon [1947] in Queensland, recommended dusting of the potato seed tubers with two per cent DDT prior to storage. The foregoing review indicates that sufficient information is not available on the biology of potato moth particularly under field condition in India. Dusting of potato tubers with DDT is not advisable, the insecticide being toxic to human beings, specially in Bihar where seed and table potatoes are not stored separately. Therefore, stress has been given in this paper on such insecticides which are not toxic to human beings. The applicability of DDT has been confined to spraying of the walls or roofs of the godown in order to effect a check on the population of the moth during the period of storage.

In order to carry out detailed investigation, I. C. A. R. sanctioned a research scheme on the pests and diseases of stored potatoes in Bihar. Work under the scheme was commenced in 1943. The following brief notes record important conclusions arising out of the investigation on the moth.

NATURE AND EXTENT OF DAMAGE

The moth causes injury to potatoes in the field as well as in the godown. The damage to the leaf is minor and is heaviest from November to February. In the case of a young plant, it does not exceed 2.13 per cent. The infection of the underground tubers starts towards the middle of February and is maximum in the month of March. At the time of harvest in February, 0.3 to 3.33 per cent of the tubers was found infected with the caterpillars. Under the sand method of storage as

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practised in 'Bihar-sharif' and 'Patna city', about 20 per cent of the potatoes get destroyed by the moth, as against cent per cent of potatoes if they are kept exposed in the godowns. The caterpillars infecting the tubers increase the rot and the rot in turn provides ideal conditions for the rapid multiplication of the pest. All the caterpillars which hatch out from the eggs laid on the eye-buds of the tubers, do not penetrate the tubers through the same eye-buds but scatter themselves on the surface of the tubers for finding suitable spots for penetration. Ordinarily an eye-bud is penetrated by a single caterpillar. Some times, the number of caterpillars within a tuber exceeds the number of its eye-buds. It is probably due to the scarcity of healthy tubers in the neighbourhood of the infected ones. A maximum of 16 caterpillars was noted within one tuber.

SOURCES OF INFECTION

Field. The possibility of the infestation reaching the field through the infested seed tubers was thoroughly investigated, and it appears that the chances of the moth emerging from under soil where the seed tubers are buried, are little. About 23.9 per cent of the caterpillars on hatching from eggs laid on the eyes of the tubers were able to penetrate the seed tubers under soil while 12.3 per cent of the caterpillars came out from infested seed and formed earthen cocoons in the proximity of the tubers. The seeds carrying eggs germinated quite well but those initially infested with caterpillars rotted due to bacterial brown rots (*Phytophthora solanacearum*). The only possible source of infection in the field is the moths which quit the stores in the month of September and settle on brinjal and tobacco seedling before migrating to potato crop in the month of November.

Stores. Infestation in the stores arises from the infested tubers brought from the field as well as by the moths flying from the field into the godowns.

BIONOMICS

Life-history

From November to January when the plants are green, the pest breeds exclusively on the foliage. During the months of February and March, when the plants dry up, the moths hide themselves amongst dry leaves on the ground or in cracks of the soil. The moths seldom fly during the day and if disturbed their flight is short and snappy. On alighting they again seek shelter. They are active in the field soon after sunset and fly about for an hour. The moths are observed flying after sunrise also in the months of February and March, but the flight is of very short duration. During the morning flight, the male moths are predominant, the proportion being three males to one female. In the stores the moths have been observed to feed on rotten potatoes. The juice of rotten potatoes increases longevity, fecundity and the ovipositional period of the moths. Honey solution can also sustain the moth (Table I). The eggs are laid on rough scars or under the torn skin of potatoes as well as on the eye-buds of the tubers. In sprouted potatoes, the eggs are laid on the base of the sprout.

TABLE I

The effect of different foods on the fecundity and the ovipositional period of the moth

Treatments	Number of trials	Average oviposition period in days	Average fecundity per female
Honey and water (1 : 10)	20	6.8	89.5
Glucose and water (1 : 10)	20	6.4	69.5
Gur and wate (1 : 10)	20	6.4	59.4
Juice of rotten potatoes	20	7.1	102.0
Juice of healthy potatoes	20	5.6	57.8
Control	20	5.2	49.7

The nectar of the flower of *Lantana camera* which grows widely in the neighbourhood of the potato fields of Bihar-sharif and Patna city, appears to be one of its natural food plants. The moths frequently visit the flowers of *Lantana camera* at dusk during February and March. The nectar of *Lantana* flower increases longevity as compared to those of 'perol' (*Luffa acutangula*) and cucumber (*Cucumis sativa*) which are also largely cultivated in these localities near the potato fields (Table II).

TABLE II

Showing the effect of different nectars on the longevity and fecundity of the moth

Nectars from	Number of moths	Average longevity	Average fecundity
<i>Lantana camera</i>	25	6 days	82.3
<i>Solanum nigrum</i>	25	5 days	39.5
<i>Cucumis sativa</i>	25	5 days	44.7
<i>Luffa acutangula</i>	25	4 days	42.8
Without food	25	3 days	52.6

The eggs are more or less oval in outline and creamy white in colour. When freshly laid, the eggs are covered by a water-soluble secretion which hardens on exposure and cements the eggs to the eye-buds of the tubers or to the surface of the leaf. As the embryonic development proceeds, the dark colour of the larval head capsule and prothoracic plate become visible. When eclosion takes place, the chorion remains behind as a colourless shell. The average incubation period is three to four days during summer and five to six days during winter.

For one or two hours before emergence, the larvae may be seen moving within the chorion of the eggs. The larva eats its way out of the chorion through an irregular opening. The newly hatched larva measures about 1 mm. in length. The mature larva attains a length of 11 mm. and is creamy-white in colour with a light brown head. The larva undergoes four moults before pupating. On foliage the young larva begins to mine the leaf soon after emergence and lives in the mine during November to January when the plants are green. It cannot penetrate the entire length of the shoot so as to reach the tuber under soil. The maximum length of the shoot bored by a larva is about an inch only. During February to March, when the eggs are laid on soil, the young larva penetrates through the cracks of the soil and bores into the tubers. In the stores, the caterpillars, when full grown come out of the tubers, crawl upwards through the layer of sand covering below two inches thick, and on reaching the surface, make sandy cocoons. If the eggs are laid on the sand under which potatoes are kept, the larva on hatching penetrates the sand in search of potatoes. The first instar caterpillars are incapable of penetrating through the sand layer even half an inch thick. Dispersal of the pest from one tuber to another also takes place in the caterpillar stage. The larval period lasts seven to five days in summer and sixteen days in winter.

The pupa is light green in colour when first formed but soon becomes dark brown. Pupae vary in size, but the average length is about 7 mm. The pupa male is slightly smaller than the female pupa. If potatoes are kept under the cover of sand, the larva makes a sandy cocoon but when the infested potatoes are kept without any cover, silken white cocoons are formed on the eyes of the tubers, between two touching tubers, in cracks of the walls and in the empty sandy cocoons lying about, in the godowns. When the pest is breeding on the tubers under soil, the full grown caterpillars utilize earth or dead leaves to construct the cocoons. When the caterpillars are feeding on the foliage, white brownish cocoons are formed. Pupation takes place in dry curled leaves on plants, or dry fallen leaves and in cracks on the ground. The pupal period lasts five to four days in summer and nine days in winter.

Mating usually takes place during the evening hours both in the field and in the stores. One male is capable of fertilizing as many as ten females during its life time. The mating of a female moth with the same male over and again does not affect the potency of their reproduction (Table III). The longevity of the male moth increases to nine days when it mates with different females as against five days when it is kept together with the same female during its life time. The trials were carried out for eight times under the same conditions.

TABLE III

Showing the number of moths fertilized by a male and total number of eggs laid by such fertilized moths

Serial number	Average number of eggs laid by female moths fertilized by one male									
Male	1	2	3	4	5	6	7	8	9	10
1	31	49	63	96	22	60	3	88	55	<i>nil</i>
2	39	126	36	2	59	10	<i>nil</i>	<i>nil</i>	<i>nil</i>	<i>nil</i>
3	15	71	86	66	86	21	51	75	99	32
4	39	27	47	23	11	57	61	55	27	<i>nil</i>
5	33	74	45	7	24	89	31	52	11	<i>nil</i>
6	10	25	56	13	70	17	39	40	36	<i>nil</i>
7	22	30	16	21	23	14	21	33	<i>nil</i>	<i>nil</i>
8	47	51	23	31	29	10	12	27	11	<i>nil</i>

An analysis of the population of the moths in different potato stores has revealed that the females are numerous more than males, the ratio being 3:2. Therefore under natural conditions also, a male may mate more than one female. Inside stores, the time for mating is between 7 p.m. and 6 p.m. while, in the fields it lasts from 4 to 5 p.m.

Oviposition occurs throughout the day and the night, but is at its maximum from 6 p.m. to 7 p.m., in summer and from 4 p.m. to 5 p.m. in winter. The moth lays eggs in depression, mostly on the under surface of the leaves during the months of November and January while during the months of February and March it lays eggs directly on the tubers if they are accidentally exposed. The fecundity of the moth is very low during the winter months (November to January). The rates of fecundity and the longevity of the moth is greater in February and March when temperature is higher (Table IV). In the stores the moths, in the absence of exposed potatoes, oviposition any object, such as walls, sand-coverings and their own sandy cocoons.

TABLE IV

Showing the fecundity and longevity of the moths in different months

Month	Average minimum temp. F.	Average maximum temp. F.	Average relative humidity per cent	Average fecundity female moths	Average longevity of female in days	Average longevity of male in days
July	83.0	87.0	77.3	85.5	5	4
August	82.5	89.4	81.8	81.0	5	4
September	84.1	88.7	76.0	68.5	5	4
October	80.1	85.9	69.0	78.0	5	4
November	68.6	78.8	60.7	58.6	4	3
December	61.8	69.0	55.0	49.5	4	3
January	68.0	80.0	64.0	67.7	4	3
February	68.0	80.0	64.0	79.7	5	4
March	72.0	86.0	73.0	82.5	5	4
April	79.2	88.6	63.6	89.8	5	4
May	86.0	102.0	51.2	105.4	5	4
June	86.8	98.2	66.2	98.1	5	4

The rate of development of the pest is accelerated with the rise of the temperature up to 38°C. The temperature 40°C. proved fatal for all the stages. The temperature 20°C. is the lower limit for its development. In laboratory trials, the fecundity of the moth decreased to 12.6 eggs in darkness as against 28.86 eggs in light. It is probably for this reason that the darker godowns in Bihar-sharif and Patna city had lower infestation. The moths are only active during dusk.

Thirteen broods were observed during the year, eight of which were in the stores and the remaining five in the field. In stores the duration of the different stages was: incubation period three to four days, larval period seven to five days and pupal period five to one day. In the field: the incubation period five to six, larval period sixteen days and pupal period nine days.

STORAGE METHODS PRACTISED IN DIFFERENT LOCALITIES

The various methods of storage practised in different localities of Bihar have been studied. The important conclusions are:

- (i) Godowns with a minimum of light but having good ventilation show lower incidence of the moth. Such a condition is obtained by fixing two or

three ventilators 1ft. \times 1ft. in size near the ceiling so that cross ventilation occurs.

- (ii) Godowns with mud wall and *kacha* floors are the best for storage during April to June, because they keep cool. The sand, the most common covering material is quite successful in checking the incidence of the pest if applied two inches thick but this increases the rot. With a view to reduce the rot, the store-keeper resorts to various devices with the advent of rainy seasons; the thickness of the sand is reduced or the tubers are transferred to the '*machan*' and kept uncovered. In some places the potato heaps are sprayed with water during April and May on alternate days to lower the temperature.
- (iii) In some cases potatoes are washed in water before they are stored. This removes nearly 30 per cent of the eggs of the moth.

The potato store-keepers are fighting against the tuber moth and rotting. The conditions which reduce the incidence of the moth, unfortunately, increase the rots and the conditions which inhibit the rots favour the moth. The potato store-keeper, therefore, tries to meet the greater of the two evils. When the season is favourable for the moth attack, the storage conditions are such as to control the moth, and when the season is not favourable for the moth, but very favourable for the rots, the store-keeper takes the risk of the moth attack and tackles the rots.

PREVENTIVE AND CONTROL MEASURES

In the store

Pretreatment. Pretreatment with various dips, e.g., anisflum, turpentine oil, pyridine, phenyl and creosote were tried as disinfectants. A dip in five per cent phenyl solution for fifteen minutes is most effective. It disinfects the tubers completely of viable eggs. Turpentine (five per cent) solution showed higher larvicidal effect but increased the susceptibility of the tuber to rots. Five per cent solution of creosote also brings about complete disinfection of the tubers from the eggs but it is liable to induce the high percentage of rots in subsequent storage of potatoes.

Covering materials. A comparative study of different covering materials had shown that one inch thick covering of sand containing pieces of garlic or crushed onion (one lb. per md. of potatoes) is better than two inches thick layer of sand lime (one inch thick) or charcoal one inch thick. Storage of potatoes on *machan* during April to June proved detrimental on account of dessication and rot, but it was helpful in reducing fungal rots during July to September. Storage on brick floor during April to June was very efficacious against heat-rot but it was not so helpful from the point of view of fungal rot during July to September. The total recovery of potatoes under sand and garlic covering was 60.83 per cent on *machan* as against 48.73 per cent on brick-floor under the same covering during the period from April to September. The recovery of potatoes increases to 65.53 per cent if potatoes are stored on the brick-floor from April to June and on *machan* during July to September under the same covering. Garlic repels the moth,

Trap. To study the possibility of petroleum oils as an attractant for the moth, the experiments were carried out at Sabour, Bihar, with kerosene oil, pine oil, turpentine oil, the proportion being one part oil and 200 parts water. The tests were carried out in an infested potato godown at Sabour by keeping the mixture over night in earthen pails and counting the catches every morning as reported in the Table V. The largest number of moths were attracted to the kerosene oil trap but the difference between these oils was not very large.

TABLE V

Baits	Days of catches							Total moths trapped
	1	2	3	4	5	6	7	
	♀ ♂	s ♂	♀ ♂	♀ ♂	♀ ♂	♀ ♂	♀ ♂	
Pine oil water 1 : 200	73 64	61 47	69 71	16 24	20 11	18 9	6 3	490
Turpentine oil : water 1 : 200	75 85	58 21	57 47	18 12	59 85	5 4	9 5	537
Kerosene oil : water 1 : 200	83 31	34 68	45 49	76 20	88 28	14 8	8 4	552
Control (water)	4 3	1 2	7 1	3 2	4 1	1 nil	nil nil	29

A suitable trap has been evolved for destroying the moths during storage in the light of above observations. It consists of 18 in. diameter earthen basin containing water with a film of kerosene oil on its surface. It may be used both during day and night in potato-stores. At the end of every week the water of the basin should be changed. The trap was repeatedly tried in the infested potato-stores at Sabour, Bihar-sharif and Patna city. In these demonstrations the catches averaged 159.3 moths per trap per day. One trap was found quite sufficient for a store-room, measuring 24ft. × 18ft. × 10ft. The kerosene oil acts as an attractant for the moths. This trap is gaining great popularity amongst the cultivators of Bihar-sharif and Patna city on account of its efficacy and cheapness.

Recent developments in the widespread use of DDT as spray on the interior surface of the buildings or store-room to control insects like house flies and mosquitoes, have necessitated exploring the possibility of the insecticide to be used in white-wash on the interior surface of the store-rooms in Bihar, to destroy the moths during the storage period. For performing preliminary trials, earthen pots fitted with lids were white-washed with chalk containing different strengths of DDT. Including the control, there were four treatments, each treatment, having three replications. In each pot along with healthy potatoes, six pairs of moths were introduced to study their fecundity and longevity. To study the residual effect of the white

wash, repeated tests were made in the same pot and it was found that the toxic effect of the wash persists for about a month. The longevity and the fecundity of the moth are very considerably reduced with three per cent DDT white-wash (Table VI). Further work on this item is in progress.

TABLE VI

Showing the longevity and fecundity of the moth under different DDT treatment

Treatment	No of trials made	Average longevity	Average fecundity
DDT (1.5 per cent)	8	4.7	42.9
DDT (2 per cent)	8	3.6	49.3
DDT (2.5 per cent)	8	1.3	21.0
DDT (3 per cent)	8	1.1	19.5
Without DDT	8	5.8	111.2

Spraying the walls of potato stores with 10 per cent solutions of phenyl and creosote after an interval of every week has proved very effective in keeping down the population of the moths in the stores. The phenyl and creosote treatments have repellent effect on the moth.

It is essential to sort out rotten potatoes and remove them from the stores at regular intervals to prevent infestation to healthy potatoes.

In the field

Harvesting of the tubers before the middle of February is recommended as it has three distinct advantages. Firstly, the infection in the harvested tubers is almost nil. Secondly, potatoes are less liable to infection by the moth during harvest as their population is very low at that time. Thirdly the temperature of the soil will be below 85°F. and there will be no risk of heat rot during subsequent storage. The potato crop becomes quite ripe for harvesting by the middle of February in Bihar. The crop usually remains for a period of three and a half months in the field.

When the irrigations are increased from six to eight during the growing period of the crop from November to February, the percentage of infection in the underground tubers at the time of harvest falls from 3.4 per cent to 0.5. The potatoes should be kept or transported in baskets treated with 10 per cent solutions of creosote or phenyl at the time of digging out potatoes from under the soil.

The control of the pest in the field by dusting or spraying does not seem practicable due to : the caterpillars either mine the leaves or under ground tubers, the eggs are usually found in depression on the under surface of the leaves and therefore not easily accessible to insecticidal sprays. The kerosene oil trap may be used at dusk for trapping the moths which are very active at that time.

SUMMARY

The potato tuber moth causes injury (i) to leaves, stems and the tubers of the growing crop in the field and (ii) to stored potatoes in the godowns. The leaf damage does not exceed 2.13 per cent during November to January. In store, about 20 per cent of the tubers get destroyed by the moths under the sand storage method. The carry over of the pest to the field does not take place through the infested seed-tubers. The only possible source of infestation in the field is the moths which fly out of stores in the month of September and settle on brinjal and tobacco seedlings before migrating to the potato crop. In stores, the infection is carried through the tubers which received infection while in the field, as well as through the moths flying from the field to potato godowns.

The moths seldom fly in day light and when disturbed, the flight is short and snappy. They are active in the field soon after sunset and the flight continues for about an hour. The moths are observed flying after sun-rise during the months of February and March. In stores the moths feed on rotten potatoes. The juice of rotten potatoes increases longevity, fecundity and the oviposition period of the moth. *Lantana camera* which grows widely in the neighbourhood of the potato-growing areas of Bihar is suspected to be one of its natural food plants. The mating of the moth usually takes place during the evening hours both in the field and the stores. One male is capable of fertilizing as many as ten females during its life time. The longevity of the moth increases to nine days when it mates with different females every day as against five days when it is kept together with the same female. Oviposition occurs throughout the day and night but it is maximum during 6 p.m. to 7 p.m. in summer and 4 p.m. to 5 p.m. in winter. On plants the young larvae mine the leaf soon after emergence and live as leaf miners during November to January. During the months of February and March the larvae infect the underground tubers in addition to leaves and stems. When the caterpillars are breeding on the tubers under soil, they utilize earth or dry leaves to produce earthy cocoons. In case the pest is breeding on the aerial parts of the plants, brownish-white cocoons are formed. The pupation takes place under dry curled leaves on plants or fallen dry leaves or in cracks of the soil. In the stores if the infected potatoes are kept under cover of sand, the larvae make sandy cocoons but when potatoes are kept without any cover, white silken cocoons are formed on the eye-buds of the tubers.

The rate of development of the pest is accelerated up to 38°C. but a temperature of 40°C. is fatal for all stages of the pest. A temperature of 20°C. is the lower vital limit. Thirteen broods of the pest were noted within a year, eight of which were in the stores and the remaining five in the field.

Thus, it will be advisable to harvest potatoes, which are to be utilized for seed purposes by the middle of February.

Dipping of potatoes in a five per cent solution of phenyl for 15 minutes disinfects the tubers completely from viable eggs. Amongst different covering materials tried, one inch thick sand covering mixed with garlic bits (1 lb. per maund of potatoes) has given the best results both on the floor and on *machan*. The total recoveries

of potatoes under the covering of sand and garlic was 60.83 per cent on *machan* as against 18.73 per cent on brick-floor. The recovery of potatoes increases to 65.53 per cent if potatoes are stored on the brick-floor from April to June and on *machan* from July to September. One kerosene oil trap is quite sufficient for a store room measuring 24 ft. \times 18 ft. \times 10 ft. Kerosene oil acts as an attractant. Spraying the walls of potato godown with ten per cent solution of phenyl or creosote after an interval of every week has proved very effective in keeping down the population of the moths in the stores.

When potatoes are harvested before the middle of February the infestation in the harvested tubers is almost nil, the potatoes are less liable to infection by the moths during harvest as their population is very low at that time, and the soil temperature remains below 80°F. at that time and therefore there is no risk of *Heat rot* during subsequent storage. When the irrigations are increased from six to eight during the growing period of the crop from November to February, the percentage of infection in the tubers at the time of harvest falls from 3.4 per cent to 0.5 per cent. Potatoes may be transported or kept in baskets treated with ten per cent solutions of phenyl or creosote to avoid the infection by the moth during harvest. The kerosene oil trap should be used particularly during dusk for trapping the moths which are very active at that time.

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NOTE

THE RAPID DETERMINATION OF MOISTURE IN PROCESSED FRUITS AND OTHER AGRICULTURAL PRODUCTS

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EXAMINATION for moisture content of any edible material is one of the essential preliminaries in passing it as a standard product, and its determination assumed greater importance during war times when such materials had to be transported long distances under difficult conditions, because on it depended the soundness of the material at the destination after long periods of transit.

The moisture in ordinary agricultural products is generally determined by drying at 100°C.-105°C. in an air-oven to constant weight. But this method is not applicable to all classes of materials, as for example, processed fruit products. Among the chief difficulties that confront the chemist in determining the moisture content of sugar-bearing materials by the ordinary methods of drying may be mentioned :

The very hygroscopic nature of such materials, and the consequent retention of water by absorption or occlusion; the extreme sensitiveness of some sugars, notably fructose, to decomposition at temperatures between 80°C. and 100°C. with the splitting off of water and other volatile products, [Jacobs, 1938], and the liability of many impure sugar-containing materials upon heating to give off various volatile products such as alcohols, aldehydes, esters, organic acids, carbon dioxide and ammonia which are wrongly estimated as water in determining the loss of weight.

The moisture determination is further complicated by the fact that many sugars like maltose, lactose and raffinose retain variable amounts of water of crystallisation under different conditions of drying so that one is not always certain, even when no further loss of weight occurs in the oven, as to the exact moisture that may be retained by a hydrated form. Even sugars containing much glucose generally give too high a result for moisture content if dried at 100°C. owing to the conversion of glucose into glucosan and caramel [Allen, 1933]. It is, therefore, clear that the ordinary methods of moisture determination cannot be suitable for sugar-bearing materials.

In such cases the low pressure drying method of the Association of Official Agricultural Chemists is recommended. But this is time-consuming requiring drying of the material at 70°C. for six hours under a pressure not exceeding 100 mm. Because of this and the uncertainty which sometimes attends the ordinary oven-drying method at 100°C.-105°C. several rapid methods have been proposed for direct

moisture determination. Such methods as distillation with immiscible solvents come under this class.

The then Directorate of Food under the Department of Supply, New Delhi, had been sending during the war years to this Institute samples of raisins, sultanas, briquetted raisins and other dried fruit products for the determination of moisture content to have a check on contractors' products before sending them abroad.

For reasons cited above the Vacuum Drying Method was accepted as the most reliable and accurate method, and accordingly moisture determinations were made by it. Perhaps with a view to be doubly sure of the moisture content before accepting the contractors' samples, the samples were being sent to other laboratories as well. We reported the moisture values to be well within the permissible limit for all samples sent to us. In the case of briquetted raisins the Military Food Laboratory at Kasauli reported a much higher figure and on that account rejected some contractors' samples claiming that the xylene distillation method they followed according to the Standard method of the Ministry of Foods, London, to be correct. They contended that in the Vacuum Oven method the entire moisture was not driven out. The rejection of the contractors' samples gave rise to a controversy between the Food Directorate and the Military Food Laboratory, and the matter was referred back to us to prove by actual demonstration that the Vacuum Oven method was the one to be adopted for dry fruits and the like and the xylene distillation method, in spite of its simplicity and rapidity, yielded abnormally high values as a result of the decomposition of fruits during the boiling of xylene.

In order to prove the destruction of sugars and the consequent increase in the moisture content, samples of fructose, glucose, saccharose, briquetted raisins and nuts were examined both by the low-pressure drying method and the xylene and toluene distillation methods for moisture. Further, reducing sugars were estimated in them before and after digestion with xylene and toluene. It was evident that the percentage of sugars after digestion with the solvents was lower than that in the original samples. Both in simple sugars and fruits there was decomposition and charring during the moisture determination by the xylene distillation method. With toluene the decomposition was less. In the case of fructose which is so abundant in fruits, the decomposition was the greatest. Fructose, in the presence of water, decomposes to oxymethyl furfural with three molecules of water. This extra water is responsible for the higher value of moisture by the xylene method [Browne, 1941].

High boiling point solvents are destructive in their action and give abnormally high values for moisture with charring. Drying in boiling xylene of raisins and briquetted raisins and nuts leads to blackening and considerable decomposition. The blackening is preceded by swelling during which the evolution of moisture is fairly normal, but high in aggregate. Water is evolved as the darkening of fruit intensifies. Fruits first dried by heating in toluene lost more water when subsequently heated with xylene.

SUMMARY

If correct values of moisture for processed fruits and other agricultural products, are desired by the rapid distillation methods, then the solvents employed must be altered according to the nature of the samples.

The toluene distillation method was found to give results comparable with the standard vacuum oven method, when the heating in an oil-bath at about 140°C. is stopped after one hour.

In this connection a short review of time and labour saving methods described in the *Journal of Institute of Brewing* [1936] should be consulted in order to enable one to choose the rapid procedure with due regard to the material on hand for which the moisture content is sought. The three methods of Tate and Warren [1936], Middleton [1931] and Lundin [1932] may be referred to.

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REVIEWS

INSECT PESTS OF COTTON IN INDIA

By H. D. NAGPAL, Indian Central Cotton Committee Publication, 1948,
Price Rs. 2

THE book gives a comprehensive list of the insect fauna associated with cotton crop and is the first publication of its kind in India.

The author deserves credit merely for compiling the information which is rather inadequate for scientific workers and is too simple and almost preliminary. The classification of pests is rather vague and does not give any clear idea about the status of the pests. At places the importance of the major pests is shadowed by including them after the minor pests. Mostly the vernacular names pertain to North India and the references are also incomplete.

The publication needs revision and considerable improvement by the addition of further details for making it useful for further critical research on cotton pests. It will be still better if the notes on important pests or on those which are likely to be of some significance are supplemented with sketches or plates to help in the identification of the pests. (K. N. T.)

DISEASES OF COTTON IN INDIA

By B. N. UPPAL, Published by Indian Central Cotton Committee, Bombay 1948,
p. 33, Price Rs. 2

THAT a crop which occupies an area of over twenty million acres in India should be attacked by several diseases due to fungi, bacteria, nematodes and viruses, is not surprising. Fortunately, a majority of these diseases in India are of minor importance, only wilt and root-rot in certain provinces and states causing anxiety to the cotton growers. But a disease of no importance today may grow into a menace tomorrow. The Indian Central Cotton Committee has, therefore, done well in bringing together the available information on these diseases and this bulletin, written by a distinguished investigator of cotton diseases, is a welcome addition to the scanty literature on the diseases of crop plants in India.

Under each disease the life-history and distribution are briefly stated, followed by an adequate description and aetiology of the disease. Control measures, wherever they are known, are given and relevant references to important literature further add to the value of the bulletin. The sections on wilt and root-rot are naturally very exhaustive, while those on anthracnose and blackarm, which appear to be not as insignificant as was once supposed, have also been dealt with in detail.

It is to be hoped that in a second edition of this bulletin, there would be a sufficient number of coloured drawings and photographs to illustrate the diseases. Bulletins of this kind should have been distributed free to cotton growers; instead a charge of rupees two, which is rather exorbitant, has been made, which is very much to be regretted. (B. B. M.)

COMMERCIAL FRUIT AND VEGETABLE PRODUCTS

By W. V. CRUESS, Published by McGraw-Hill Book Company Inc., New York,
3rd Edition, 1948, pp. 906, Price \$8.50

THIS internationally distinguished author and his well-read book need no special introduction to the readers. His book has served for over twentyfour years all students of food technology and horticulture and in this third edition the author has put in lots of new material and data as well as many new illustrations. These represent various phases of developments in the science of food technology during the past many years especially in canning, freezing and dehydration. A singular addition to this new edition is the chapter on 'Plant Sanitation' which deals with a very essential and important aspect of in food processing particularly in the recent years. All the materials have been presented up to date.

The book has covered all the principles and commercial applications of canning, freezing and dehydration of fruits and vegetables, beverage making, manufacture of jams, jellies, marmalades, fruit and vegetable concentrates, pickle making, wine and vinegar making, etc. Some chapters cover the various aspects of spoilage and their control in, utilisation of waste fruits and vegetables and disposal of wastes. An interesting chapter on packing cases and other methods of packing has also been briefly presented. At the end of each chapter a useful reference list of books, bulletins and original articles on the various subjects has been given, which will be of considerable help those who want to go deep into the details.

The subject of fruit technology has shown great progress and possibilities and it is rather difficult to write a single and comprehensive book covering canning, freezing, dehydration, etc., since each one of the branches might well be dealt with in separate volumes. In this edition the credit goes to the author in presenting the whole field in an instructive and informative manner, giving most of the up to date details on the various branches of fruit technology without sacrificing any of the fundamental principles and fresh advances.

The book is recommended to all those engaged in the fruit industry as well as to all the students and teachers of fruit technology. It is the only outstanding 'all-in-one' compilation so far available dealing with all the processes involved in the manufacture of fruit products and in fruit preservation. The fruit world must be greatly indebted to the author for putting his life-time study and energy in this new edition for its benefit. (G. S. C.)

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*Soils and Fertilizers	35s.	*Animal Breeding Abstracts	35s.
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Reference to literature, arranged, alphabetically according to author's names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets; when the author's name occurs in the text, the year of publication only need be

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If a paper has not been seen in original it is safe to state 'original not seen'. Sources of information should be specifically acknowledged.

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